

March 2008

DEFENSE ACQUISITIONS

2009 Is a Critical Juncture for the Army's Future Combat System



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Highlights of [GAO-08-408](#), a report to congressional committees

Why GAO Did This Study

The Future Combat System (FCS) program—which comprises 14 integrated weapon systems and an advanced information network—is the centerpiece of the Army's effort to transition to a lighter, more agile, and more capable combat force. The substantial technical challenges, the Army's acquisition strategy, and the cost of the program are among the reasons why the program is recognized as needing special oversight and review. Section 211 of the National Defense Authorization Act for Fiscal Year 2006 requires GAO to report annually on the FCS program. This report includes an examination of (1) how the definition, development, and demonstration of FCS capabilities are proceeding, particularly in light of the go/no-go decision scheduled for 2009; (2) the Army's plans for making production commitments for FCS and any risks related to the completion of development; and (3) the estimated costs for developing and producing FCS.

What GAO Recommends

GAO recommends that the Secretary of Defense: establish criteria that the FCS program will have to meet in the 2009 milestone review in order to justify continuation; identify viable alternatives to FCS; and take other actions. DOD concurred with GAO's recommendations.

To view the full product, including the scope and methodology, click on [GAO-08-408](#). For more information, contact Paul Francis at (202) 512-4841 or francisp@gao.gov.

March 2008

DEFENSE ACQUISITIONS

2009 Is a Critical Juncture for the Army's Future Combat System

What GAO Found

The progress made during the year by the FCS program, in terms of knowledge gained, is commensurate with a program in early development. Yet, the knowledge demonstrated thus far is well short of a program halfway through its development schedule and its budget. This portends additional cost increases and delays as FCS begins what is traditionally the most expensive and problematic phase of development. Thus, FCS's demonstrated performance, as well as the reasonableness of its remaining resources, will be paramount at the 2009 milestone review for the FCS program. In the key areas of defining and developing FCS capabilities, requirements definition and preliminary designs are proceeding but not yet complete; critical technologies are immature; complementary programs are not yet synchronized; and the remaining acquisition strategy is very ambitious.

Beginning in 2008, the Army plans to make a series of commitments to produce FCS-related systems in advance of the low-rate production decision for the FCS core program in 2013. In general, production commitments are planned before key information is available. In 2008 and 2009, the Army plans to begin funding production of the first of three planned spin outs of FCS technologies to current forces. However, its commitment to the first spin out may be made before testing is complete. Also starting in 2008, the Army intends to commit to production of early versions of the Non-Line-of-Sight Cannon. This commitment is being made to respond to congressional direction to field the cannon. FCS technologies, network, and designs are not yet mature enough for production, and thus the cannons produced will not be deployable without significant modifications. Advance procurement funding for the first full suite of FCS systems will begin in fiscal year 2011, the budget for which will be presented to Congress in February 2010—less than a year after the milestone review and before the stability of the FCS design is assessed at the critical design review. In addition, the Army plans to commit to using Boeing, its lead system integrator, for the early production of FCS systems through the initial production phase of the FCS system of systems. By the time of the production decision in 2013, \$39 billion will have already been invested in FCS, with another \$8 billion requested. Thus, while demonstration of the FCS's capability falls late in the schedule, commitments to production are likely to come early—an untenable situation for decision makers.

The Army's \$160.9 billion cost estimate for the FCS program is largely the same as last year's but yields less content as the number of FCS systems has since been reduced from 18 to 14. There is not a firm foundation of knowledge for a confident cost estimate. Also, two independent cost assessments are significantly higher than the Army's estimate. However, the Army maintains that it will further reduce FCS content to stay within its development cost ceiling. Should the higher cost estimates prove correct, it seems unlikely that the Army could reduce FCS content enough to stay within the current funding constraints while still delivering a capability that meets requirements.

Contents

Letter		1
Results in Brief		2
Background		5
Knowledge Has Been Gained on FCS Definition, Development, and Demonstration but Falls Well Short for a Program at Midpoint		9
Production Commitments Are Planned to Be Made Early Despite Late Demonstration of FCS Capabilities		32
FCS Costs Likely to Be Higher Than Current Army Estimate		40
Conclusions		49
Recommendations for Executive Action		50
Agency Comments and Our Evaluation		52
Appendix I	Scope and Methodology	55
Appendix II	Comments from the Department of Defense	56
Appendix III	Technology Readiness Levels	59
Appendix IV	FCS Critical Technology Ratings and Projections for Achieving TRL 6	61
Appendix V	Annual and Cumulative FCS Research and Development Funding and Planned Events and Achievements	63
Related GAO Products		64
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Tables		
Table 1: FCS Critical Technology Maturation—Actual and Projected		17
Table 2: Key FCS Test Event Schedule		29

Table 3: Comparison of the Original Cost Estimate and Recent Cost Estimates for the FCS Program (in billions of dollars)	41
Table 4: FCS Procurement Funding through 2013	47

Figures

Figure 1: FCS's Core Systems	6
Figure 2: Flow and Number of FCS Requirements	10
Figure 3: Comparison of TRL 6 Projections	18
Figure 4: Differences between Best Practices Acquisition Approach and FCS Approach	26
Figure 5: FCS Knowledge Gaps	27
Figure 6: NLOS-C versus Core FCS Procurement Schedule	36
Figure 7: Cumulative FCS Research and Development Funding and Key Events	45
Figure 8: FCS Research and Development and Procurement Funding Profile from Fiscal Year 2003 through Fiscal Year 2030	48

Abbreviations

APS	active protection system
CAIG	Cost Analysis Improvement Group
CDR	critical design review
DOD	Department of Defense
FCS	Future Combat System
FRMV	FCS Recovery and Maintenance Vehicle
FRP	full-rate production
GAO	Government Accountability Office
IDA	Institute for Defense Analyses
JTRS	Joint Tactical Radio System
KP1	knowledge point 1
KP2	knowledge point 2
KP3	knowledge point 3
LSI	lead system integrator
LRIP	low-rate initial production
NLOS-C	Non-Line-of-Sight Cannon
NLOS-LS	Non-Line-of-Sight Launch System
NLOS-M	Non-Line-of-Sight Mortar
PDR	preliminary design review
R&D	research and development

SOSCOE	system-of-systems common operating environment
TRL	technology readiness level
UAV	Unmanned Aerial Vehicle
WIN-T	Warfighter Information Network-Tactical

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**United States Government Accountability Office
Washington, DC 20548**

March 7, 2008

Congressional Committees

The Future Combat System (FCS) program—which comprises 14 integrated weapon systems and an advanced information network needed for a brigade combat team—is the centerpiece of the Army's efforts to transition to a lighter, more agile, and more capable combat force and, according to the Army, the greatest technology and integration challenge it has ever undertaken. The Army seeks to develop and then integrate dozens of new technologies in the FCS program and ultimately create a force in which people, platforms, weapons, and sensors are linked seamlessly together in a system of systems.

The Army started the FCS program in May 2003 before defining what the systems were going to be required to do and how they would interact. The Army moved ahead without determining whether the concept could be successfully developed with existing resources—without proven technologies, a stable design, and available funding and time. The Army projects the FCS program will cost \$160.9 billion, which does not include all the costs to the Army, such as complementary programs. The Army is using a unique partner-like arrangement with a lead system integrator (LSI), Boeing, to manage and produce the FCS. For these and other reasons, the program is recognized as being high risk and needing special oversight. Accordingly, in 2006, Congress mandated that the Department of Defense (DOD) hold an FCS milestone review following the FCS preliminary design review, which is now scheduled for February 2009.¹ Congress directed that the review include an assessment of whether (1) the needs are valid and can be best met with the FCS concept, (2) the FCS program can be developed and produced within existing resources, and (3) the program should continue as currently structured, be restructured, or be terminated. Congress required the Secretary of Defense to review and report on specific aspects of the program, including the maturity of critical technologies, program risks, demonstrations of the FCS concept and software, and a cost estimate and affordability assessment.

¹ John Warner National Defense Authorization Act for Fiscal Year 2007, Pub. L. No. 109-364, § 214 (2006).

Given its cost, scope, and technical challenges, section 211 of the National Defense Authorization Act for Fiscal Year 2006 requires GAO to report annually on the FCS program.² The specific objectives of this report are to address (1) how the definition, development, and demonstration of FCS capabilities are proceeding, particularly in light of the go/no-go decision scheduled for 2009; (2) the Army's plans for making production commitments for FCS and any risks related to completing development; and (3) the estimated costs for developing and producing FCS and risks the Army faces in both meeting the estimate and providing commensurate funding. We are issuing a second report to address FCS network and software development.³

In conducting our work, we have contacted numerous DOD and Army offices. We reviewed documents pertaining to the FCS program, including the *Operational Requirements Document*, the *Acquisition Strategy Report*, technology assessments, and modeling and simulation results; attended meetings at which DOD and Army officials reviewed program progress; and held discussions with key DOD and Army officials on various aspects of the program. Officials from DOD and the Army have provided us access to sufficient information to make informed judgments on the matters in this report. In addition, we drew from our body of past work on weapon systems acquisition practices. We performed our work from March 2007 to March 2008 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. Appendix I further discusses our scope and methodology.

Results in Brief

The progress made during the year by the FCS program, in terms of knowledge gained, is commensurate with a program in early development. Yet, the knowledge demonstrated thus far is well short of a program halfway through both its development schedule and its budget. This portends additional cost increases and delays as FCS begins what is

² Pub. L. No. 109-163, § 211.

³ GAO, *Defense Acquisitions: Significant Challenges Ahead in Developing and Demonstrating Future Combat System's Network and Software*, GAO-08-409 (Washington, D.C.: Mar. 7, 2008).

traditionally the most expensive and problematic phase of development. Accordingly, FCS's demonstrated performance as well as the reasonableness of its remaining resources will be paramount at the 2009 milestone review for the FCS program. Specifically, in the key areas for defining and developing FCS capabilities, we found:

- Requirements have been defined well enough to begin preliminary designs of the individual FCS systems. Requirements are still fluid, reflecting recent events such as the Army's decision to reduce systems from 18 to 14, understanding what the FCS network needs to be, and the re-estimate of software from 63 million to 95 million lines of code.
- FCS's 44 critical technologies are approaching the basic maturity needed to start a program, but are immature for a program halfway through its scheduled development. Most FCS technologies may not be fully mature until after 2009. Beyond basic technology maturity, major integration challenges lie ahead.
- Complementary programs—needed to meet FCS requirements but managed outside the program—are not yet synchronized with the FCS schedule and face their own technical, funding, and requirements challenges. Two programs critical to the FCS network—the Joint Tactical Radio System (JTRS) and the Warfighter Information Network-Tactical (WIN-T)—have been restructured several times.
- The strategy for completing the second half of FCS development is ambitious. According to DOD policy, a program at the midpoint of development should be at the critical design review—the point at which the design is stable and ready to be demonstrated with high-fidelity prototypes. FCS is still a year away from preliminary design, and by the time of critical design review in 2011, there will be only 2 years left before the production decision. To meet this schedule, FCS will not test production-representative prototypes before low-rate production, and key system-of-systems testing will not take place until after production starts.

Beginning in 2008, the Army plans to make a series of commitments to produce FCS-related systems in advance of the production decision for the FCS core program in 2013. In general, production commitments are planned before key information is available. In 2008 and 2009, the Army plans to begin funding initial production of the first of three planned spin outs of FCS technologies to current forces. The Army intends to commit to the first spin out before testing is complete and will rely partly on tests of surrogate systems. Also starting in 2008, the Army plans to commit to

production of early versions of the Non-Line-of-Sight Cannon (NLOS-C). This commitment is being made to respond to congressional direction to produce and field the cannon. FCS technologies, network, and designs are not yet mature enough for production, and thus the cannons produced will not be deployable without significant modifications. In addition, the Army recently decided to commit to using its LSI for the production of spin outs, cannons, and the first three sets of FCS core systems. This makes the Army's relationship with the LSI even closer and will heighten oversight challenges. By the time of the 2013 production decision, a total of about \$39 billion will already have been appropriated for FCS, with another \$8 billion requested. Thus, while demonstration of the FCS capability falls late in the schedule, commitments to production will come early—an untenable situation for decision makers.

The Army's \$160.9 billion cost estimate for the FCS program is largely the same as last year's estimate but yields less content as the number of FCS systems has since been reduced from 18 to 14. Given the program's relative immaturity, there is not a firm foundation of knowledge for a confident cost estimate. Also, two independent cost assessments—one from DOD's Cost Analysis Improvement Group (CAIG) and the other from the Institute for Defense Analyses (IDA)—are significantly higher than the Army's estimate. Both assessments estimate higher costs for software development, to which the recent increase in lines of code adds credence. Nonetheless, the Army has not accepted these estimates and instead uses its own, lower estimate in making funding projections and maintains that it will further reduce FCS content to stay within its development cost ceiling. As the Army begins a steep ramp-up of FCS production, FCS costs will compete with other Army funding priorities, such as the transition to modular organizations and recapitalizing the weapons and other assets that return from current operations. Together, the program's uncertain cost estimate and competing Army priorities make additional reductions in FCS's scope and capabilities likely.

We are making several recommendations to the Secretary of Defense in regard to (1) establishing objective and quantifiable criteria that the FCS program will have to meet at the 2009 go/no-go decision, (2) identifying viable alternatives to FCS to be considered if FCS does not meet the established criteria, and (3) closely examining the Army's relationship with the LSI, particularly regarding the LSI's expanded responsibilities for production. In commenting on a draft of this report, DOD concurred with our recommendations.

Background

The FCS concept is designed to be part of the Army's Future Force, which is intended to transform the Army into a more rapidly deployable and responsive force that differs substantially from the large division-centric structure of the past. The Army is reorganizing its current forces into modular brigade combat teams, each of which is expected to be highly survivable and the most lethal brigade-sized unit the Army has ever fielded. The Army expects FCS-equipped brigade combat teams to provide significant warfighting capabilities to DOD's overall joint military operations. The Army is implementing its transformation plans at a time when current U.S. ground forces continue to play a critical role in ongoing conflicts in Iraq and Afghanistan. The Army has instituted plans to spin out selected FCS technologies and systems to current Army forces throughout the program's system development and demonstration phase.

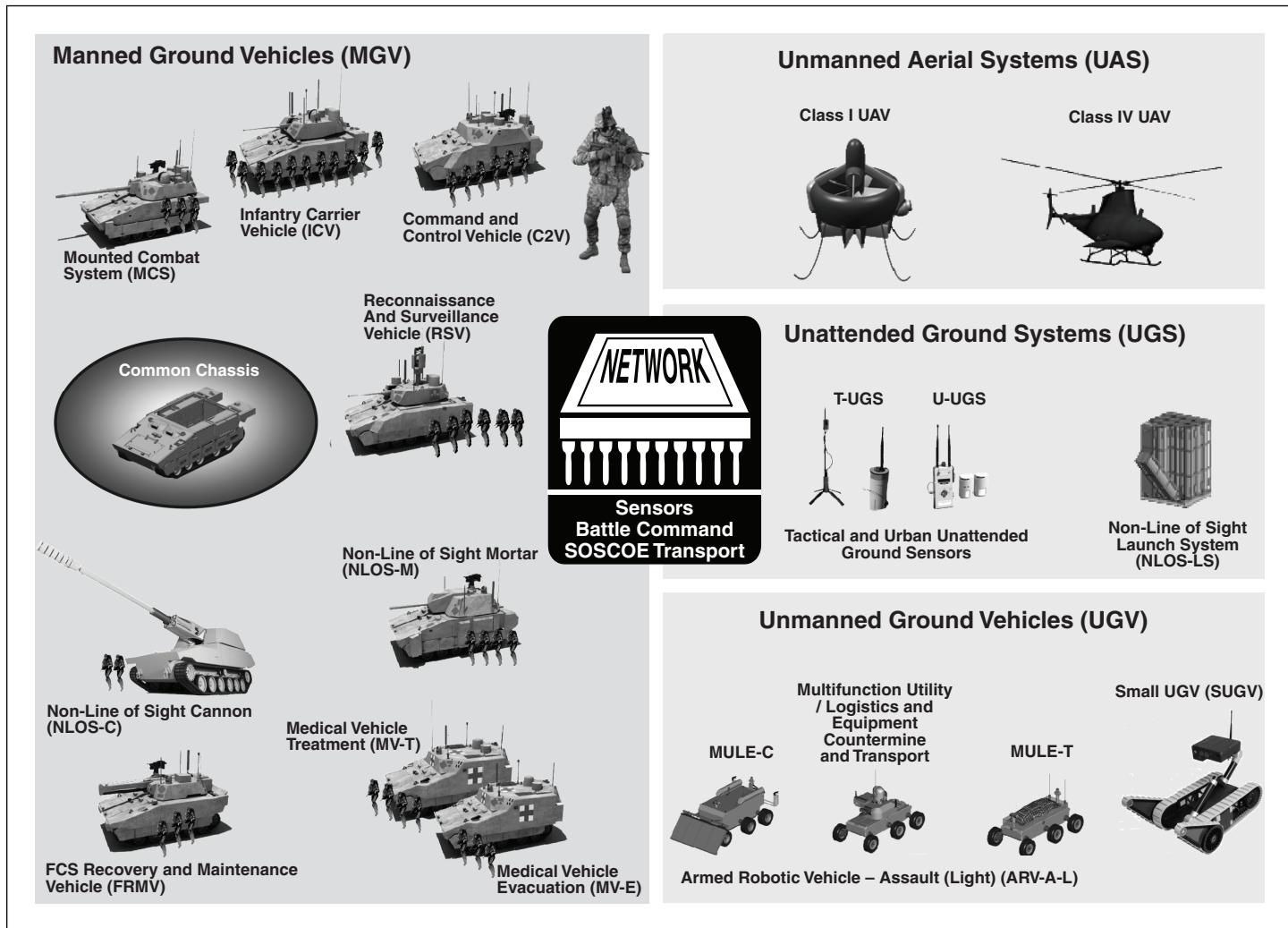
The Army recently made a number of adjustments to its plans for the FCS program. The revised program will no longer include all 18 systems as originally planned. The FCS family of weapons is now expected to include 14 manned and unmanned ground vehicles, air vehicles, sensors, and munitions that will be linked by an advanced information network. The systems include

- eight new types of manned ground vehicles to replace current tanks, infantry carriers, and self-propelled howitzers;
- two classes of unmanned aerial vehicles;
- several unmanned ground vehicles; and
- an attack missile.

Fundamentally, the FCS concept is to replace mass with superior information—allowing the soldier to see and hit the enemy first rather to rely on heavy armor to withstand a hit. This proposed solution attempts to address a mismatch that has posed a dilemma to the Army for decades: the Army's heavy forces had the necessary firepower needed to win but required extensive support and too much time to deploy while its light forces could deploy rapidly but lacked firepower. If the Future Force were to become a reality, then the Army would be better organized, staffed, equipped, and trained for prompt and sustained land combat, qualities intended to ensure that the Army would dominate over evolving, sophisticated threats. The Future Force is to be offensively oriented and will employ revolutionary concepts of operations, enabled by new technology. The Army envisions a new way of fighting that depends on

networking the force, which involves linking people, platforms, weapons, and sensors seamlessly together in a system of systems.

Figure 1: FCS's Core Systems



Source: U.S. Army.

If successful, the FCS system-of-systems concept would integrate individual capabilities of weapons and platforms, thus facilitating interoperability and open system designs. This concept would represent significant improvement over the traditional approach of building superior individual weapons that must be retrofitted and netted together after the fact. This transformation, in terms of both operations and equipment, is

under way with the full cooperation of the Army warfighter community. In fact, the development and acquisition of FCS is being accomplished using a uniquely collaborative relationship among the Army's developers, the participating contractors, and the warfighter community.

The Army is using a management approach for FCS that centers on an LSI to provide significant management services to help the Army define and develop FCS and reach across traditional Army mission areas. Because of its partner-like relationship with the Army, the LSI's responsibilities include requirements development, design, and selection of major system and subsystem contractors. The team of Boeing and its subcontractor, Science Applications International Corporation, is the LSI for the FCS system development and demonstration phase of acquisition, which is expected to extend until 2017. The FCS LSI is expected to act on behalf of the Army to optimize the FCS capability, maximize competition, ensure interoperability, and maintain commonality in order to reduce life-cycle costs, and for overall integration of the information network. Boeing also acts as an FCS supplier in that it is responsible for developing two important software subsystems. Army representatives stated they did not believe the Army had the resources or flexibility to use its traditional acquisition process to field a program as complex as FCS under the aggressive timeline established by the then-Army Chief of Staff. The Army will maintain oversight and final approval of the LSI's subcontracting and competition plans.

In 2007, we reported on, among other things, why the Army decided to use an LSI for the FCS program and the nature of the LSI's working relationship with the Army.⁴ We found that the use of an LSI for FCS provides an oversight challenge for the Army and that the Office of the Secretary of Defense has an important role in providing oversight on the FCS program. Congress has expressed concern over the use of LSI's, and has prohibited DOD from awarding new contracts for LSI functions after October 2010.⁵

⁴ GAO, *Defense Acquisitions: Role of Lead Systems Integrator on Future Combat Systems Program Poses Oversight Challenges*, GAO-07-380 (Washington, D.C.: June 6, 2007).

⁵ National Defense Authorization Act for Fiscal Year 2008, Pub. L. No. 110-181, § 802.

Knowledge-Based Processes Necessary for Successful Development

Since the mid-1990s, we have studied the best practices of leading commercial companies.⁶ Taking into account the differences between commercial product development and weapons acquisitions, we have articulated a best practices product development model that relies on increasing knowledge when developing a new product. This knowledge-based approach requires developers to make investment decisions on the basis of three specific, measurable levels of knowledge at critical junctures over the course of a program:

- Knowledge Point 1: At program start, the customer's needs should match the developer's available resources in terms of mature technologies, time, and funding. Indications of this match include having firm requirements in place as well as demonstrated maturity of technologies needed to meet customer needs. A preliminary design review at or near the start of product development is typically the vehicle used to help stabilize performance, schedule, and cost expectations.
- Knowledge Point 2: About midway through development, the product's design should be stable and demonstrate that it is capable of meeting performance requirements. A critical design review at this mid-point is the vehicle for making the determination and generally signifies the point at which the program is ready to start building production-representative prototypes.
- Knowledge Point 3: By the time of the production decision, the product must be shown to be producible within cost, schedule, and quality targets and have demonstrated its reliability. It is also the point at which the design should demonstrate through realistic testing that it performs as expected.

The most important part of a knowledge-based approach occurs at program start, when product development begins. At that point, a timely match of requirements and resources is critical to successful product development. A key difference between successful products—those that perform as expected and are developed within estimated resources—and problematic products is when the match is achieved. When a customer's needs and a developer's resources are matched before a product's development starts, it is more likely the development will result in a successful product that is able to meet cost, schedule, and performance

⁶ See "Related GAO Products" in this report.

objectives. When this match takes place later, after the product development is underway, problems occur that can significantly increase the expected time and money as well as result in performance shortfalls.

Knowledge Has Been Gained on FCS Definition, Development, and Demonstration but Falls Well Short for a Program at Midpoint

Because the Army went forward with FCS development before attaining key knowledge such as firm requirements and mature technologies, its knowledge levels have consistently lagged behind its calendar schedule. It will be a challenge for the Army to mature technologies and hold a preliminary design review by 2009. Ideally, these processes should have been completed by the program's start in 2003. Moreover, the Army has just recently formed an understanding of what the FCS network needs to be and what may be technically feasible. The Army is still struggling to synchronize the set of needed complementary programs with FCS's content and schedules because many of these programs have technical or funding issues of their own. As it has gained knowledge in these areas, the Army has had to restructure the program, reducing scope, increasing cost, and delaying schedule. In 2009, the Army will have spent 6 years and \$18 billion on these initial definition and development efforts. That leaves about 4 years and \$9 billion in development funding to complete what are usually the more costly aspects of a development program—system integration and demonstration activities as well as preparation for production. The Army's user community believes, based on modeling and simulation analyses, that FCS will provide needed capabilities. However, it will be several years before demonstrations validate those results. In fact, system demonstrations to date have been limited and broad system-of-systems demonstrations will not be conducted until late in the program.

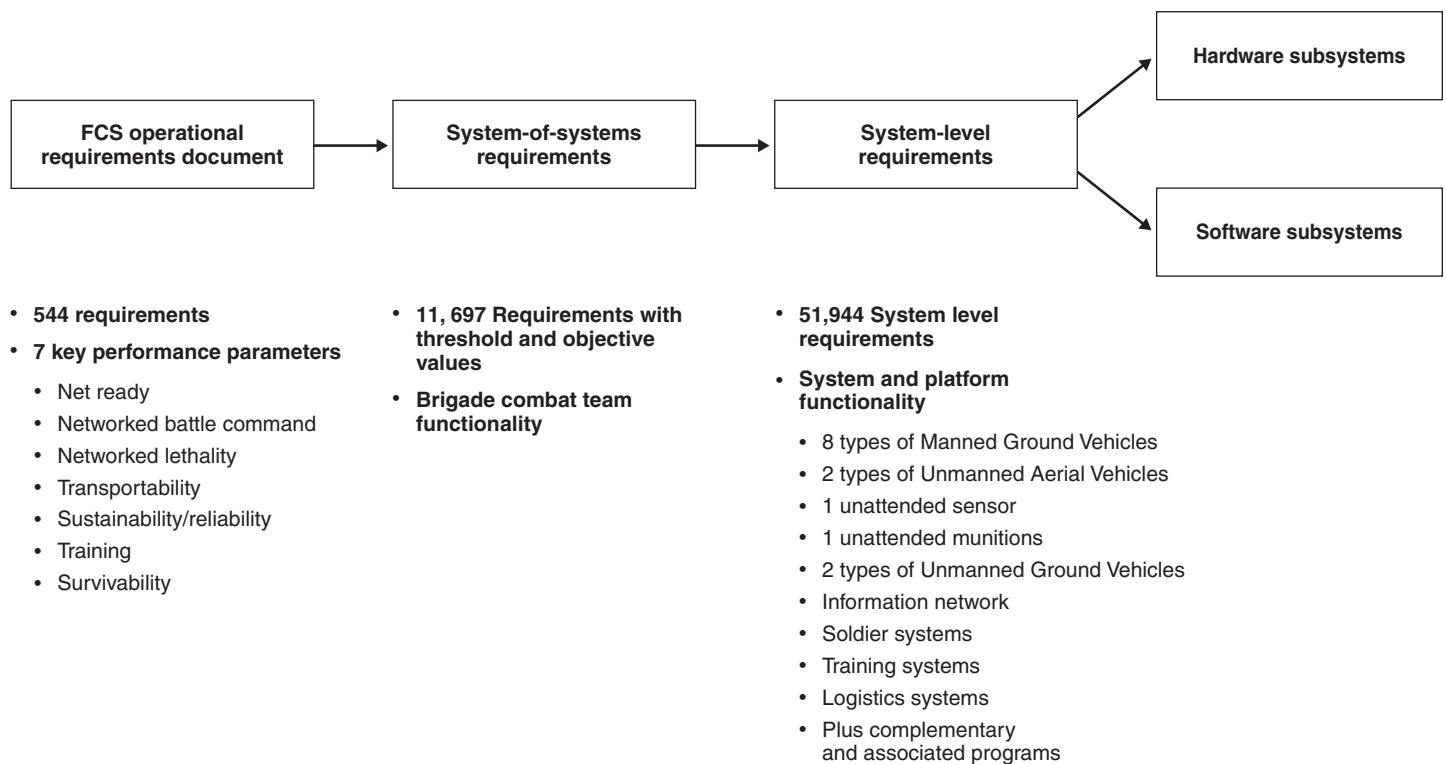
FCS Requirements Not Yet Fully Defined, and System Designs Are Not Yet Complete

Ideally, the Army should have shown a match between customer needs and available resources by having established firm requirements and preliminary designs that meet those requirements shortly after program start in 2003. Instead, the Army expects to continue the process of setting and defining requirements and establishing system designs at least until the program reaches its system-of-systems level preliminary design review in 2009. This is particularly problematic because 2009 actually marks a date that is about one year past the mid-point of the FCS development phase, when a program following best practices and DOD policy would normally conduct a critical design review to show it has a stable, producible design that is capable of meeting performance requirements.

The Army faces a daunting task in completing requirements definition by 2009. As figure 2 illustrates, the FCS program encompasses thousands of

requirements at the operational, system-of-systems, and individual system levels.

Figure 2: Flow and Number of FCS Requirements



Source: U.S. Army (data); GAO (analysis and presentation).

The Army anticipates that it will gain a better understanding of FCS system and subsystem requirements—and resolve many of the remaining “to be determined” and open issues—during a series of system-level preliminary design reviews to be completed by February 2009. Army officials acknowledge that system-level requirements are almost certain to be modified in the process as subsystem hardware and software are more fully defined.

The Army is working through the detailed requirements changes needed to implement the program adjustments announced in early 2007 because the restructure of FCS from 18 to 14 systems resulted in requirements modifications, deferral, and redistribution. Army officials told us they are currently assessing the requirements balance among the 14 systems and do not yet have all the modifications to system requirements in place.

However, some consequences are already apparent. For example, a requirement for the deferred Class II unmanned aerial vehicle to carry a laser designator is to be assigned to the Class I aerial vehicle. According to Army officials, the Class I aerial vehicle will consequently need to use a more powerful engine. In addition, because of the deferral of the Class III aerial vehicle, its mission requirements—including performing the mine detection mission—will need to be assigned to other platforms.

All the individual FCS systems are being designed to meet the system-level requirements and restrictive space, weight, and power constraints. The Army is still coming to terms with these and other design issues. It has not finished making trade-offs between requirements and design and have not yet finalized decisions about how to implement requirements within several areas of concern, including weight, power, space, reliability, and unit costs. For example, most of the manned ground vehicles are at risk of not meeting their weight, maintainability, and other requirements. To that end, the program is still working on designing a hull for manned ground vehicles that not only meets weight constraints but also requirements for protecting vehicle crews against mine blasts. Similarly, the program is trying to confirm a design that will balance competing requirements for the Class I unmanned aerial vehicle to perform as needed yet be small and light enough to be carried in a soldier's backpack. It is not clear that the Army will be able to complete all system designs by 2009.

The Army is also working to reduce recognized technical risks in the system designs in order to meet system-of-systems as well as system-level FCS requirements. For example, the Army is considering the possibility of modifying requirements for the Class IV unmanned aerial vehicle because the vehicle may not fully meet FCS electromagnetic requirements. Likewise, the Army has focused on modifying transport requirements for manned ground vehicles because they are too heavy to be moved via the Air Force's C-130 airlift aircraft as originally planned.

Incomplete Requirements and Designs for FCS Information Network Hamper Software Development

Despite significant efforts to date, the Army and LSI have not completed defining the detailed network requirements, maturing the preliminary design of the network, and developing and integrating network hardware and software. Nearly 5 years after the start of system development, the Army and LSI only recently reached an understanding of what the network needs to be, what may be technically feasible, how to begin building the network, and how to eventually demonstrate it. An engineering approach has been identified but network design and maturity is still a work in

progress. For example, the Army and LSI are still determining what network management means in terms of

- what is needed to support each specific mission (radios, routers, satellites, computers, information assurance devices, policies);
- how to allocate network resources to the mission spectrum (storage, throughput, bandwidth); and
- how to fuse, process, and present extensive FCS sensor data to appropriate users.

The Army and LSI are also working to establish how to maintain the network, such as

- how to monitor status and performance of the network (hardware faults, network quality of service, overall performance);
- how to implement spectrum management to ensure connectivity and avoid interference; and
- how to reconfigure the network in real time based on network conditions and mission critical traffic.

As they move ahead, the Army and LSI are faced with significant management and technological challenges that place development of FCS's network and software at risk. The magnitude, size, and complexity of the network and software development are unprecedented in DOD history. The Army and LSI have identified and need to address numerous areas of high risk such as enterprise network performance and scalability, immature network architecture, quality of service on a mobile ad-hoc network, end-to-end interoperability with strategic networks of the global information grid, and synchronization of FCS with WIN-T and JTRS programs, which still do not have mature technologies and are at risk of having delayed or incomplete delivery of capabilities to FCS. Finally, a recent study by IDA found that the FCS program would likely experience additional cost growth because of unplanned software effort, unplanned rework during operational testing, and additional work to address system-of-systems integration, validation, and performance issues identified

during testing after the critical design review.⁷ Each of these areas would affect network and software development, but the Army believes that IDA did not consider the impact of the Army's mitigation efforts.

Although the requirements process for the FCS information network is not yet complete, the LSI and many of its subcontractors are developing and testing FCS software. In total, five major software builds are planned. Software Build 0 is complete and Build 1 is being tested. The most significant issue identified to date is the growth in the estimates of the total amount of software to be developed for FCS. Early in the program, the Army and LSI projected that about 32 million lines of code would be needed. Later, that estimate was increased to about 63 million lines of code. As the Army continues to define FCS hardware and software subsystem requirements, a new estimate puts the total volume of software at about 95 million lines of code. The Army and LSI attribute this latest increase to factoring the operating system software, something that had not been included previously, into their estimate. In terms of actual experience, the lines of code in Build 0 were about 6 percent greater than projected and Build 1 were about 17 percent greater than projected.⁸

Although the Army and LSI have implemented disciplined software practices for developing the network and software, the aggressive pace of the program and Army decisions on what it can afford to do during development have caused requirements issues at the software developer level. While the Army and LSI have implemented practices that have proved successful at leading software companies, such as the use of repeatable and managed development processes and use of a structured management review process to ensure quality development, we found that the immature definition of system-level requirements was causing problems. For example, the software developers for the 5 of the 52 major software packages we reviewed report that high-level requirements provided to them for decomposition and refinement were poorly defined, omitted, or delivered late to the software development process. Also, we found that poor or late requirements development have had a cascading effect as late delivery or poorly defined requirements on one software development effort, in turn, caused other software development efforts to be delayed. For example, four of the five software developers report that

⁷ This study was required in the John Warner National Defense Authorization Act for Fiscal Year 2007, Pub. L. No. 109-364, § 216.

⁸ Software data in Build 1 is a cumulative total that includes software from Build 0.

problems with late requirements have caused them to do rework or to defer requirements out to future builds because of insufficient time. These software developers report that schedule compression caused much of this strain which could have been averted if they had been allowed sufficient time to adequately understand and analyze the requirements.

Army's User Representative Believes FCS Will Still Provide Needed Capabilities

Although the Army has not yet demonstrated the technical feasibility of FCS's expected capabilities, the Army's user representative expects that FCS will provide capabilities that will be as good as or better than current forces.⁹ The user representative's position is based on the results of a series of modeling and simulation activities. However, it will be several years before field demonstrations validate those results. The user representative has a key role in assessing whether FCS can deliver capabilities that meet operational requirements. According to an Army Training and Doctrine Command official, the user representative's current position is that FCS, in either an 18- or 14-system configuration, is expected to provide needed capabilities and will be as good as or better than current forces.

The official stated that the user representative's position is based on the results of modeling and simulation analyses conducted to date. The Army relies heavily on these modeling and simulation analyses in the early phases of FCS in cases where actual or live test assets are not available. To that end, these analyses began in 2003 and will continue throughout the development program. Together, the analyses collectively postulate that an FCS-equipped force will outperform current forces on many levels, including the ability to affect a larger area of operations, accomplish assigned missions faster, survive as well or better, kill earlier at longer ranges, and better leverage and enable more effective joint operations. In referencing the analyses and conclusions to date, the Army official noted that the Army's decision to decrease the number of FCS systems from 18 to 14 did not affect the FCS brigade combat team's likely capability to prevail in the simulated conflicts. However, while the Army has performed modeling and simulation analyses with both 18 and 14 systems, it did not make a direct comparison of the projected capabilities of FCS with 18 systems and FCS with 14 systems because changes in data and other modeling aspects precluded such a comparison.

⁹ The Army's Training and Doctrine Command acts as the FCS user representative, and in that capacity, it serves as a warfighter advocate and counterpart to the FCS program manager and is responsible for the centralized management of all user activities during the FCS development program.

The official added two caveats to the user community's current position. He pointed out that true FCS capability at all levels will not be known until demonstration and testing of actual physical assets is conducted. Additionally, he noted that the user community will not accept FCS if it does not meet minimum operational requirements. However, he did indicate that the user community might accept some parts of FCS if it did not meet minimum requirements but yielded systems that were badly needed and/or performed better than other weapon systems available at that time.

The user community's optimism about FCS capabilities may be premature. The Army already has stated that the program adjustment from 18 to 14 systems saved money but put at risk FCS's ability to reach its full tactical and operational potential. Furthermore, it has indicated that the adjustment reduced the individual capability of each of the 15 projected FCS brigade combat teams. At this point, it is unclear exactly what FCS capability can be realistically expected because modeling and simulation results will not be fully validated by actual demonstrations and testing until well in the future. For example, most of the manned ground vehicle prototypes are not expected to be available until 2011 for developmental and qualification testing. As noted by IDA in its 2007 report, what is known is that the Army has little experience in developing system-of-systems and in designing for a whole system to be more capable than the sum of its parts. Moreover, according to IDA, experience teaches that the simulated behavior of individual systems and system of systems almost certainly fails to capture important aspects of live behavior.

Key Assessments Planned to Inform 2009 Milestone Review for FCS

In commenting on our March 2007 FCS report, DOD indicated that the Defense Acquisition Board, in alignment with the FCS system-of-systems' preliminary design, would conduct a number of critical assessments to support the department's FCS acquisition and budget decisions.¹⁰ It identified one of these as a systems engineering assessment that would evaluate the executability of the FCS program and will focus on many key areas including requirements development and management, understanding the system-of-systems dependencies and interfaces, design and requirements trade-off processes, and risk assessment and mitigation plans. DOD also stated that a second assessment, to be conducted by the

¹⁰ GAO, *Defense Acquisitions: Key Decisions to Be Made on Future Combat System*, GAO-07-376 (Washington, D.C.: Mar. 15, 2007).

Joint Staff, will evaluate the FCS's capabilities relative to its role in joint force applications.

Critical Technologies and Complementary Programs Put FCS at Significant Risk

Almost 5 years and \$12 billion into development, FCS's critical technologies remain at low maturity levels. According to the Army's latest technology assessment, only two of FCS's 44 critical technologies have reached a level of maturity that based on best practice standards should have been demonstrated at program start. Even applying the Army's less rigorous standards, only 73 percent can be considered mature enough to begin system development today. This is not to suggest that the technology maturation should have proceeded more smoothly or more quickly. Rather, the state of FCS technologies accurately reflects the unpredictable nature of the discovery process that attends technology development, which is why it is best done before development of a system is formally begun. The technological immaturity, coupled with incomplete requirements, is a mismatch that has prevented the Army from reaching the first critical knowledge point for this program—a precursor for cost growth. Many of these immature technologies may have an adverse cumulative impact on key FCS capabilities such as survivability. In addition, the Army is struggling to synchronize the schedules and capabilities of numerous essential complementary programs with the FCS program.

FCS Critical Technologies Not Yet Sufficiently Mature

Maturing technologies to Technology Readiness Level (TRL) 7 (fully functional prototype demonstrated in an operational environment) prior to starting product development is a best practice and a DOD policy preference. (See app. III for a complete listing and description of TRLs.) For the FCS, this degree of maturity would have meant having had all technologies at TRL 7 by May 2003; today, it only has two that have reached that level. Although DOD policy prefers the best practice standard, it does accept a lower standard—TRL 6 (system model or prototype demonstrated in a relevant environment). However, only 32 of FCS's 44 critical technologies have attained that lower standard of maturity almost 5 years after starting product development. Army officials do not expect to mature all FCS's critical technologies to this lower standard until at least the preliminary design review in 2009, at least 6 years late. (App. IV contains a list of all FCS critical technologies with their 2006 and 2007 TRL ratings and Army projections for attaining TRL 6.)

Army engineers do not track a technology's progress once it reaches TRL 6. They maintain that anything beyond TRL 6 is a system integration

matter and not necessarily technology development. We do not agree with this position as integration often involves adapting the technologies to the space, weight, and power demands of their intended environment. To a large extent, this is what it means to achieve TRL 7. This is work that needs to be accomplished before the critical design review and is likely to pose additional trade-offs that the Army will have to make to reconcile its requirements with what is possible from a technology and engineering standpoint. Table 1 shows the number of FCS critical technologies that have matured to different levels during the program's history and presents the Army's projections through the production decision.

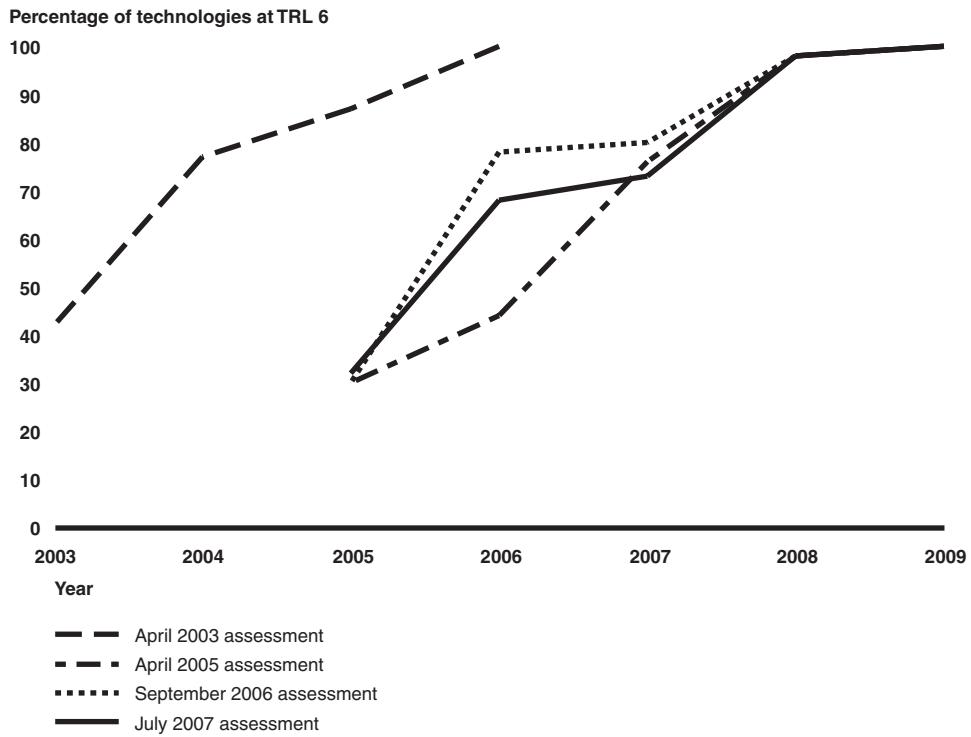
Table 1: FCS Critical Technology Maturation—Actual and Projected

Development Start	August 2006	July 2007	2009 Preliminary design review	2011 Critical design review	2013 Production decision
TRLs \geq 7	0	1	2	2	5
TRLs = 6	10	34	30	41	39
TRLs \leq 5	42	11	12	1	0

Source: U.S. Army (data); GAO (analysis and presentation).

Throughout the 5 years of FCS development, multiple Army assessments illustrate that the maturation of critical technologies has not been predictable. Although the Army has matured a few critical technologies since last year, it is behind the ambitious pace it had set just 2 years ago (see fig. 3).

Figure 3: Comparison of TRL 6 Projections



When the development effort began in 2003, the Army expected to have 100 percent of FCS's critical technologies matured to a TRL 6 by 2006. Since that time, the Army has updated its projections on numerous occasions. Each of those revised estimates assumed that almost all of FCS's critical technologies would be mature to TRL 6 by 2009, in time for the program's preliminary design review. (Currently, the threat warning sensor for the active protection system is not expected to be mature to TRL 6 until sometime in 2010.) The Army's September 2006 assessment projected that 80 percent of FCS critical technologies would mature to TRL 6 by 2007, while the most recent assessment revealed that only 73 percent of those technologies have actually satisfied the conditions of TRL 6.

While the September 2006 critical technology assessment suggested progress, the most recent assessment revealed that the Army misjudged the maturity of a few critical technologies and that the projected dates for other technologies achieving TRL 6 have slipped. According to the Army's latest technology assessment, two technologies have reached full maturity

(TRL 7)—Health Monitoring and Casualty Care Intervention and Excalibur Precision Munitions. According to Army analyses, the maturity assessment for Health Monitoring and Casualty Care Intervention is based on existing technology being fielded to Stryker brigades. Nevertheless, FCS vehicles have not been produced yet, and integration of this technology onto those vehicles will ultimately determine their true maturity for FCS. The first increment of Excalibur is being used by existing howitzers, but recent Army reports identified a risk that the round may not be entirely compatible with the proposed NLOS-C design. Even for these mature systems, the Army must be aware of the potential integration issues, which may not reveal themselves until the Army more fully develops the FCS platform designs. Despite these examples, other technologies are now rated less mature, projected maturity dates have slipped, and others have shown little advancement over the years.

Since the start of the program, the Army has reduced the ratings of seven FCS critical technologies. Five of these critical technologies are still rated as less mature than they were in previous assessments, and three of those adjustments happened within the past year. Last year, the active protection system was rated as a TRL 6, but the Army had based this assessment on a concept that was not ultimately selected for further development in FCS.¹¹ Instead, the Army selected an active protection concept that was less mature, but which the Army believed was a better design for satisfying all FCS active protection requirements. Consequently, the Army's most recent assessment rated the active protection system as a TRL 5. Two WIN-T technology ratings were also adjusted to better reflect their maturity. The WIN-T program has a turbulent history, including technical challenges, and is being restructured in an effort to improve program execution. As a result, the assessed maturity of WIN-T technologies was reduced.

While the Army did manage to advance the maturity of six FCS critical technologies, this progress must be put into context. Because some critical technologies that were approaching full maturity were removed and the TRLs of other technologies were reduced, it effectively counteracted the progress achieved over the past year. This condition resulted in FCS technologies advancing at a slower pace than anticipated. In addition, some technologies have matured only one level over nearly 5 years of

¹¹ GAO, *Defense Acquisitions: Analysis of Processes Used to Evaluate Active Protection Systems*, GAO-07-759 (Washington, D.C.: June 8, 2007).

development. Distributed Fusion Management is the technology that correlates the large amounts of sensor data from numerous sensor sources and ultimately contributes to the maintenance of the common operational picture created with data from the distributed network nodes. Fusing sensor data is important for creating situational awareness and enabling FCS forces to see first and understand first. This technology had been assessed as TRL 4 when the FCS program began development 5 years ago and advanced to TRL 5 in the Army's most recent assessment.

Based on the Army's current assessment, eight FCS critical technologies were assessed as being no more mature, and in some cases even less mature, than they were when the program began. For example, Rapid Battlespace Deconfliction, which is designed to help manage airspace and airborne assets and potentially reduce the risk of collisions, was rated TRL 6 at the time of the first independent assessment and has since been reduced to a TRL 5. In almost 5 years of FCS development, the Army has not yet advanced the maturity for quality of service algorithms. These algorithms are vitally important for ensuring successful operation of the FCS network, particularly in regard to the Army's desire for FCS forces to see first, understand first, act first, and finish decisively. Failure to provide a high quality of service network will significantly degrade force effectiveness, and could have devastating consequences in a force that trades armor for information. Further, aided target recognition, which aids FCS in seeing and acting first and contributes to survivability, has been rated a TRL 5 since the FCS program began.

The uneven nature of the technology assessments, coupled with the lack of progress for some technologies, does not inspire confidence that the Army can successfully mature all FCS critical technologies to TRL 6 in time for the preliminary design review in 2009. While the most recent assessments were conducted by the Army without independent review, the Army expects to have an independently reviewed assessment available for the 2009 preliminary design review. This assessment should provide an objective technical opinion regarding the status of FCS critical technologies, enabling more knowledgeable decisions at the 2009 milestone review.

Immature Technologies Have Cumulative Effects: Survivability as an Example

While the performance of individual technologies is important, the potential collective or cumulative effect they can have on the performance of FCS is also important. The multiple technologies that are critical to FCS survivability are illustrative. The FCS concept for survivability breaks from tradition because it involves more than just heavy armor to protect

against impacts from enemy munitions. Instead, FCS survivability involves a layered approach that consists of detecting the enemy first to avoid being fired upon; if fired upon, using an active protection system to neutralize the incoming munition before it hits the FCS vehicle; and finally, having sufficient armor to deflect those munitions that make it through the preceding layers. Each of these layers depends on currently immature technologies to provide the aggregate survivability needed for FCS vehicles. Many of the technologies intended for survivability have experienced problems in development or have otherwise made little progress in maturity over the 5 years of the FCS program. To the extent these technologies do not mature or under-perform, the effect on overall survivability must be assessed. This also holds true for other key performance parameters, such as lethality, sustainability, and networked battle command.

The first several layers of defense best illustrate the fundamental FCS concept of replacing mass with superior information in order to see and hit the enemy first rather than relying on heavy armor to withstand a hit. These layers rely on critical technologies that are largely unproven and that have not yet demonstrated that they can provide adequate information superiority as a substitute for heavy armor to protect Army soldiers. One such critical technology is the JTRS. According to the Army's most recent critical technology assessment, JTRS radios have achieved a TRL 6. However, according to the JTRS program office, there are three JTRS subtechnologies that have not yet matured to the point where the entire radio can be rated a TRL 6. Another critical technology that contributes to FCS's first layer of survivability is wideband networking waveforms, which work in conjunction with the JTRS radios. A host of technology, cost, and schedule problems have slowed waveform and radio development, and in 2006, DOD approved a JTRS program restructure to address these problems. However, the restructure is incomplete, and waveform development is behind schedule.

The active protection system is part of the comprehensive FCS hit avoidance system architecture and will protect the vehicles from incoming rounds, like rocket-propelled grenades and antitank missiles. The Army has rated this technology as TRL 5. According to the most recent critical technology assessment, the Army expects to mature most of the active protection system suite to TRL 6 by fiscal year 2008. The Army does not expect the active protection system sensor to mature to TRL 6 until sometime after the 2009 preliminary design review. Based on current test schedules, the Army could demonstrate TRL 6 for the short-range solution by that time. However, a number of test events for the short-range

solution, some of which inform future events, have slipped. In addition, demonstration of the long-range solution to TRL 6 is not scheduled to happen until fiscal year 2010. The Army must also address the potential repercussions from blast fragmentation and the corresponding risk of collateral damage and fratricide.

The Army has been developing lightweight hull and vehicle armor as a substitute for traditional, heavy armor. The Army is developing lightweight armor for FCS vehicles in three iterations. The Army believes the first version will satisfy FCS threshold protection and weight requirements and is planned to be used in the manned ground vehicle prototypes. The Army has begun development of a second armor iteration with the goal of formulating materials that will meet FCS objective survivability requirements, but Army engineers do not expect those designs to be lighter than the first iteration's designs. The third armor iteration will focus on weight reduction initiatives with the goal of satisfying objective requirements for both protection and weight. The Army hopes that the third iteration will be ready to use in the initial production of the manned ground vehicles.

During the first iteration, Army engineers formulated a number of different armor recipes in an attempt to satisfy threshold vehicle protection requirements. They have tested a number of these recipes using smaller sample sizes called coupons, but only more robust testing of larger representative armor samples will determine whether the proposed solutions will provide the necessary protection. The Army plans to conduct such testing later this year on larger-scale samples of the different armor recipes. The Army believes this testing will prove the armor technology to TRL 6. However, should this approach fail, the Army plans to use heavier hull and vehicle armor that will require trade-offs for space and weight.

The overall survivability of FCS-equipped units will depend not only on the contribution of technologies to each layer of survivability, but also on the cumulative contribution from layer to layer. For example, if the information network, active protection, and armor each under-perform by 10 percent, the Army will first have to know this and second be able to assess the cumulative impact on overall survivability. As system-level requirements are defined and allocated, and technologies demonstrate their actual capabilities, additional design trades may be necessary and concessions made that could impact key performance parameters like lethality, survivability, sustainability, and networked battle command.

Synchronizing FCS with Complementary Programs Is a Continuing Challenge

In addition to the 14 systems and the network that compose the FCS program, its full capabilities depend on at least 50 complementary programs managed outside of FCS, some of which are also critical technologies. The Army has been unable to fully synchronize the schedule and content of the FCS program with that of complementary programs. The Army has identified problems that raise concerns about the likelihood that many complementary systems will deliver the required capabilities when needed. In some cases, complementary programs have faced funding issues due to evolving FCS requirements, and there are examples where lack of coordination between FCS and complementary program officials have stalled efforts aimed at synchronizing programs and resolving cost, schedule, and technical issues.

When the FCS program began, the Army concluded that it would need to interoperate or integrate with as many as 170 other programs to help FCS meet its operational requirements. The Army has stated previously that as many as 52 of these programs are essential for meeting FCS key performance parameters. As a result, the Army closely monitors these programs to determine if they are synchronized with the cost, schedule, and performance expectations of the FCS program. While the Army has produced a list of complementary programs that need management attention, that list has fluctuated, and although many complementary programs have been mainstays on the list, the Army has had difficulties synchronizing the schedules and capabilities of those systems with FCS.

A number of challenges have contributed to the Army's inability to synchronize complementary programs with FCS. A few of these challenges are presented below.

- Both the JTRS family of programs and the WIN-T program are facing technology maturation problems of their own, and they are at risk of delayed or reduced delivery of capabilities to the FCS program.
- Some complementary programs are not adequately funded to conduct the additional development activities needed to satisfy FCS requirements. For example, the Army wants to integrate an upgraded variant of the Javelin missile onto the Armed Robotic Vehicle-Light to defeat tanks at close range, but the Javelin program has not secured funding for this effort. In another case, the Army planned to use the MK-44 precision air burst munition to satisfy a requirement that infantry vehicles have the ability to defeat light armor vehicles and groups of soldiers at short ranges. Based on Army analyses, the MK-44

will not satisfy the antipersonnel portion of the requirement, and no funding is available to improve the round's performance.

- As the Army continues examining complementary programs, it is discovering unanticipated technical and integration issues that were not evident earlier. For example, the Army plans to use Excalibur rounds with the NLOS-C, but engineers have discovered some compatibility issues that are being addressed. In a similar assessment of the Airborne Surveillance, Target Acquisition, and Mine Detection System, the Army discovered a number of issues that included performance requirement gaps, software integration gaps, and a risk that onboard processing may not be sufficient to execute the required missions.
- In some cases, ineffective coordination has created situations where either FCS requirements were not adequately defined for key complementary programs or significant technical issues were not promptly addressed. FCS engineers discovered problems with JTRS radios related to storage temperatures and shock and vibration on the FCS ground vehicles. Efforts to resolve this problem have stalled because not all the affected parties have been included in the joint engineering team dialogue. In another example, JTRS requirements are not aligned with current force vehicles. The FCS program has not received a unified set of requirements from the user representative for spin out 1 current-force vehicles.

Complementary programs have their own acquisition and development challenges, much like the FCS program, and they have their own approved requirements documents and acquisition program baselines that cannot easily be changed—hence the difficulties in synchronizing the schedule and content of the FCS with that of the complementary programs.

FCS officials have been revising the list of essential complementary programs, in part because of the risks revealed during the synchronization process, but also in response to the Army's competing budget priorities. Program officials said they planned to complete the revised list by the end of calendar year 2007, but that has not occurred yet. Instead, Army leaders have acknowledged the problems associated with the synchronization of FCS with its complementary programs and will have to refocus their efforts and work to improve the situation. They did not promise an immediate resolution and acknowledge that FCS program officials may have to temper their expectations for complementary programs because the Army may be unable to afford all the systems that were once

considered “essential.” Part of the solution may also involve building FCS capabilities over time.

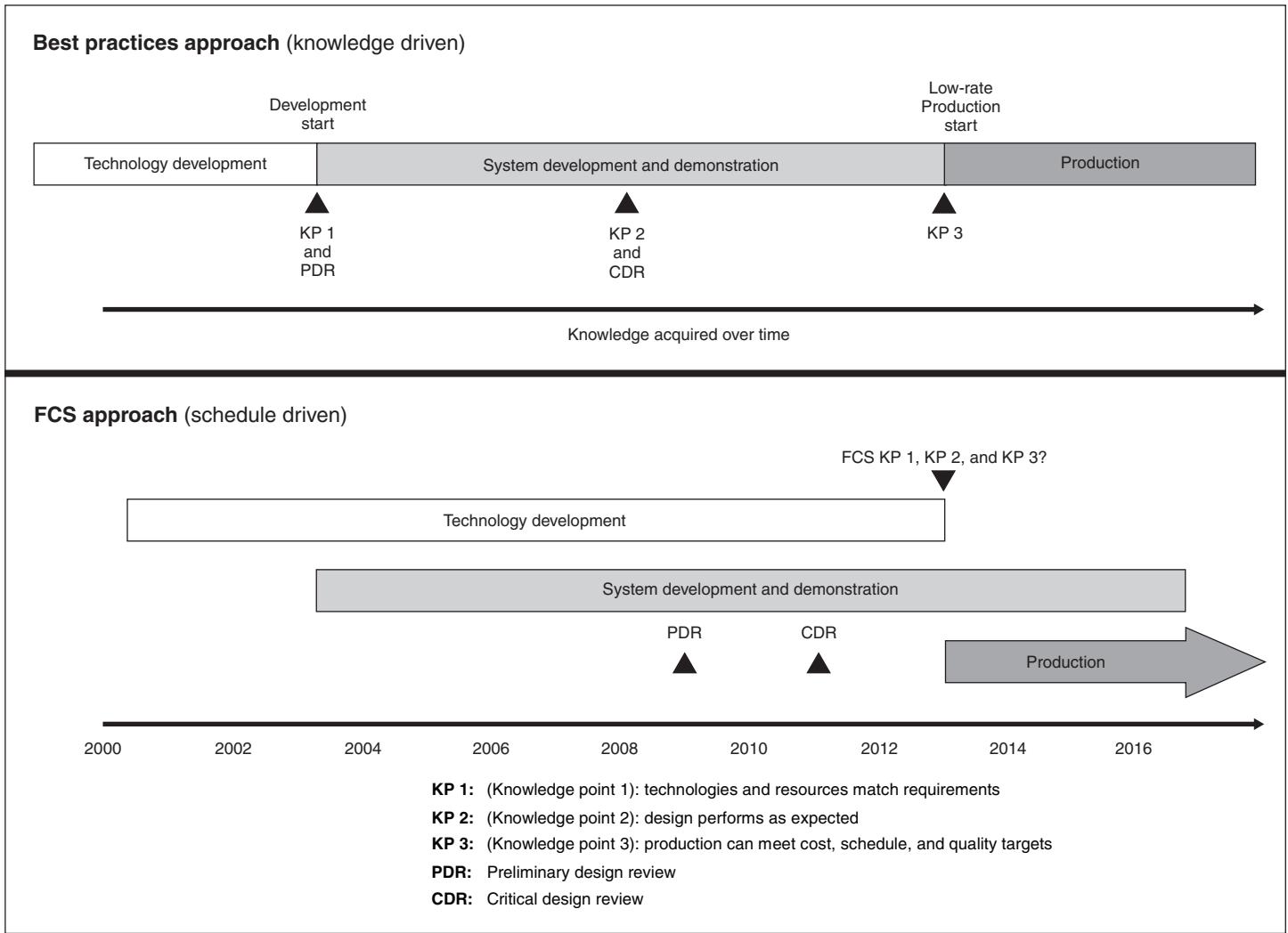
Finally, the Army and LSI have much work to do to define the interfaces not only between FCS systems and the complementary programs but also with the FCS system-of-systems. Some 500 interface documents—which describe the mechanical, electrical, and logical interface between two subsystems or systems for those systems to work together—will ultimately be needed. The Army and LSI have completed 61 as of late 2007 and expect to complete about 261 by the time of the preliminary design review in 2009.

**Schedule-Driven
Acquisition Strategy Will
Demonstrate FCS
Capabilities after Key
Decision Points**

When FCS reaches its planned preliminary design review in 2009, the Army will have expended over 60 percent of its development funds and schedule. Much still needs to be done with the remaining 40 percent of resources—including technology maturation, system integration and demonstration, and preparation for production—in short, attaining all three knowledge points fundamental to an acquisition. Although the manned ground vehicle designs depend on the performance of the information network, demonstration of the network will take place after the vehicles are designed and prototyped. Most tests to demonstrate whether the FCS system-of-systems performs as required will take place after the low-rate production decision, precluding opportunities to change course if warranted by test results and increasing the likelihood of costly discoveries in late development or during production. The cost of correcting problems in those stages is high because program expenditures and schedules are less forgiving than in the early stages of a program.

Figure 4 compares a knowledge-based approach to developing a weapon system (consistent with DOD policy) with the approach taken for FCS.

Figure 4: Differences between Best Practices Acquisition Approach and FCS Approach



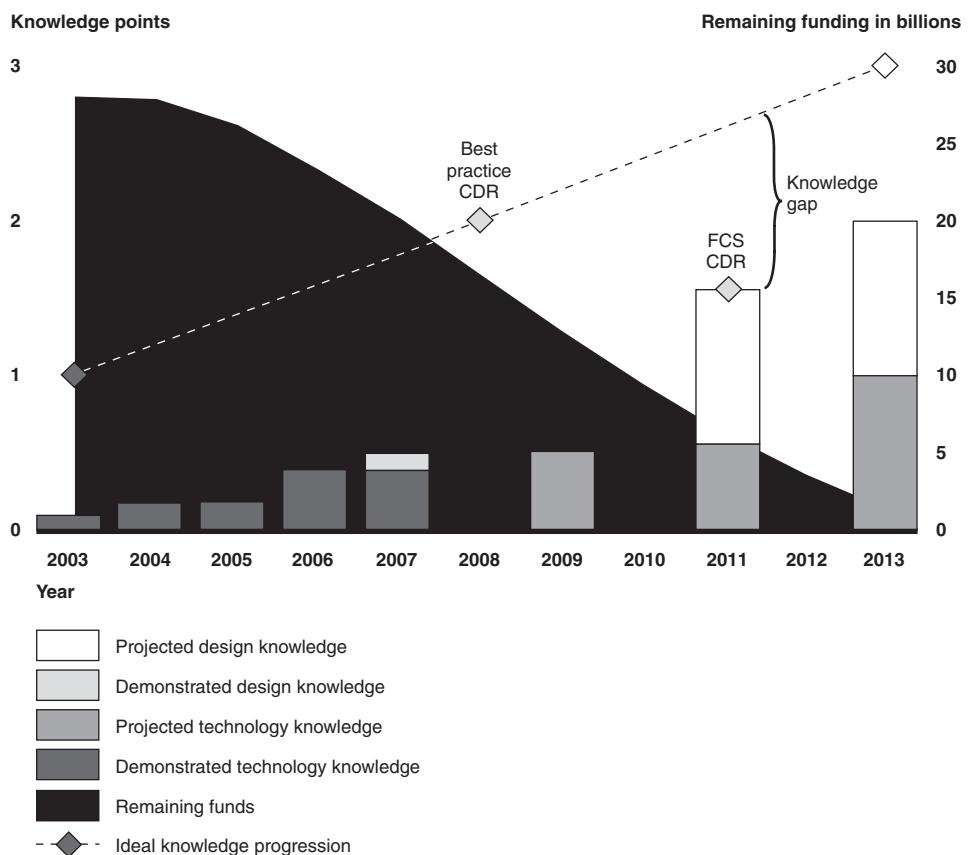
Source: Army (data); GAO (analysis and presentation).

Under a knowledge-based approach, the FCS program would have achieved a match between requirements and resources before entering system development and demonstration. If the match had occurred in 2003, the FCS program would have held its preliminary design review some 3 to 5 years ago, have nearly completed design integration by now, and be approaching a critical design review in the next year. However, the Army moved ahead with the program's start without having this match in place, and consequently, the technology development and system development and demonstration phases will overlap by several years. Now, the Army is moving towards another set of

major decision points, the preliminary design review in 2009 and subsequent milestone review, and it may not have sufficient knowledge for these reviews either.

As illustrated in figure 5 below, the program has numerous knowledge gaps that must be closed before the performance of the FCS, as well as its cost and schedule, can be stated with confidence.

Figure 5: FCS Knowledge Gaps



Source: U.S. Army (data); GAO (analysis and presentation).

The first gap between technology maturity and firm requirements has persisted since 2003, as discussed earlier. The second gap occurs at the program's critical design review, scheduled for 2011. Ideally, this review, which confirms that a design performs as expected, occurs about halfway through a program's development schedule. In the case of FCS, the program will be 80 percent of the way through its development schedule

and cost before the review is held. Furthermore, the schedule leaves little time to gain knowledge between the critical design review (knowledge point 2) and the low-rate initial production decision (knowledge point 3) because the Army has scheduled only 2 years between these events.

Moreover, the critical design review is typically the point at which a program begins building the fully integrated, production-representative prototypes whose testing will prove the design's maturity and form the basis for a low-rate initial production decision. Instead, the FCS will rely on earlier, less mature prototypes. Therefore, a decision to proceed into low-rate production will be made without a mature design, and will likely lead to costly rework or further delays.

The FCS network illustrates knowledge gaps that the Army faces in developing the FCS system—a substantial amount of development work remains before the Army and LSI can demonstrate the full expected capability of the FCS network. To date, only basic network concepts, such as connecting and exchanging information among limited network nodes, has been demonstrated (Experiment 1.1). The Army plans to demonstrate introduction and use of sensor information during this year's spin out demonstration; other incremental demonstrations will follow. The first major demonstration of FCS network is limited user test number 3, scheduled for fiscal year 2012, which will be at least a year after critical design review and about a year before the start of core FCS production. Recently, Congress legislated that a network demonstration be held prior to obligation of FCS production funding at Milestone C.¹² Even with this test, by then, other FCS system developments—such as manned ground vehicles—will have had their critical design reviews; their developmental prototypes will be in testing; and they will be getting ready to start initial production in fiscal 2013. Well in excess of 80 percent of planned development funds will have been expended by this point in time. In short, the manned ground vehicles may be proceeding well in advance of network development and demonstration, given that their designs—and in fact, the entire FCS—depend on the network's performance. At this point, it is not certain what level of network demonstration will be needed before decision makers can confidently approve manned ground vehicles and other FCS systems for initial production.

FCS testing is particularly risky in terms of its relation to demonstration of design and production process maturity (knowledge point 3) because

¹² Pub. L. No. 110-181, § 211.

testing of actual capabilities occurs late in the program—shortly before and after major decision points, including the low-rate production decision in 2013. Moreover, the period for testing, analyzing, fixing, and retesting is both too late and too short to support major decisions. The majority of testing through 2012 is limited in scope and more aimed at confidence-building than demonstrating key capabilities. Early test efforts focus on experiments and development testing of individual systems. Most development prototypes will not be available until 2010 and later for testing and demonstrations. Table 2 below shows the schedule for FCS key test events.

Table 2: Key FCS Test Event Schedule

No.	Event	Systems	Description	Dates as of 3/07	Dates as of 10/07
1	Experiment 1.1	Ground sensors and other emulators, radio systems, and other systems	Provides early and limited assessment of abilities of selected network systems	7/06 to 6/07	Complete
2	Experiment 2	Command and control, ground sensors, communications, lethality enablers, and other systems	Early experiment with several FCS systems at the battalion, company, and platoon echelons	1/08 to 1/09	7/06 to 7/08
3	Spin out 1 Technical Field Test	Unmanned Ground Sensors, Non-Line-of-Sight Launch System, Vehicle Kits	Controlled field test of systems included in spin out 1 to current forces		2/08 to 3/08
4	Spin out Limited User Test 1	Various computer systems, ground sensors, and missile launch system	Battalion level test with current force equipment and selected systems being “spun out” to current forces	3/08 to 4/08	6/08 to 7/08
Preliminary design review				2nd quarter fiscal year 2009	Same
Defense Acquisition Board milestone review				3rd quarter fiscal year 2009	Same
5	Early Ground Vehicle Delivery	Early prototype of the Non-Line-of-Sight Cannon manned ground vehicle	Initial prototype with commonality with later prototypes	3rd quarter fiscal year 2008	Same
6	Integrated Mission Test 2	Integration laboratory, simulations, common operating system and other items	First system-of-systems test in integration phase 2 and indicator of network functionality	8/09 to 11/10	2nd and 3rd quarter fiscal year 2010
7	Aerial Vehicle	Prototype of the Class IV Fire Scout	First flight of class IV unmanned aerial vehicle in integrated qualification testing	3/10	11/2010
8	Spin out 1 Technical Field Test 2	Surrogate ground vehicles with spin out 1 systems	Field test of maturing FCS network and battle command		4/10 to 7/10

No.	Event	Systems	Description	Dates as of 3/07	Dates as of 10/07
9	Limited User Test 2	Small number of unmanned aerial vehicles and a task organized platoon	Assess network maturity and capabilities of aerial vehicles in operational environment	2/10 to 4/10	3rd and 4th quarter fiscal year 2010
10	Spin out 1 Production Technical Field Test	Production unmanned ground sensors, vehicle kits, Non-Line-of-Sight Launch System	Controlled field test of production systems included in spin out 1 to current forces		4/10 to 7/10
11	Spin out 1 Initial Operational Test	Various computer systems, ground sensors, and missile launch system	Operational test of selected systems and their effectiveness with current forces	4th quarter fiscal year 2010	1st quarter fiscal year 2011
12	Experiment 3	Command, control, communications, computer, sensors, Non-Line-of-Sight Cannon, surrogate platforms	Demonstrate the integration of selected FCS communications, displays, sensor components and capabilities, unmanned air and ground systems, Non-Line-of-Sight Cannon, and lethality and logistics enablers		12/09 to 7/10
Critical design review				2nd quarter fiscal year 2011	Same
13	Preproduction Prototypes Delivery	Non-Line-of-Sight Cannon and other manned ground vehicles	Preproduction prototype delivery of manned ground vehicles with common features	3rd quarter fiscal year 2010 to 4th quarter fiscal year 2011	3rd quarter fiscal year 2008 to 4th quarter fiscal year 2012
14	Technical Field Test 3	Field test of the brigade combat team with prototypes	Important test that deals with maturing the network and confirms important interfaces and interoperability	10/11 to 3/12	2nd quarter fiscal year 2012 to 3rd quarter fiscal year 2012
15	Integrated Qualification Test 3	All manned ground vehicles and remaining unmanned ground vehicles, aerial vehicles and ground sensors	Integrated qualification tests for majority of FCS systems including preproduction representative prototypes in their core threshold configurations	8/10 to 1/12	2nd quarter fiscal year 2010 to 1st quarter fiscal year 2013
16	Limited User Test 3	Some of all systems deployed in two companies with the network	Assesses the brigade combat team small unit capabilities	4/12 to 5/12	4th quarter fiscal year 2012 to 1st quarter fiscal year 2013
Low-rate initial production decision				2nd quarter fiscal year 2013	Same
17	Production and Deployment Technical Field Test 1	Production core FCS systems	Controlled field test of core FCS systems		4/14 to 8/14

No.	Event	Systems	Description	Dates as of 3/07	Dates as of 10/07
18	Integrated Verification Testing	All FCS platforms	Specification verification and evaluation of production platforms		10/13 to 12/16
19	Production and Deployment Limited User Test	All manned ground vehicles and some unmanned systems	Complete full-up system-level tests of all systems to production standards	4th quarter fiscal year 2014	4th quarter fiscal year 2014 to 3rd quarter fiscal year 2015
Initial operating capability				3rd quarter fiscal year 2015	Same
20	Live Fire Test	All individual systems	Live fire tests with complete and functional systems	2014 to 2016	4th quarter fiscal year 2014 to 4th quarter fiscal year 2016
21	Initial Operational Test & Evaluation	Brigade combat team and all of the systems involved	Full spectrum operations with production representative systems in a realistic, operational live environment	3rd and 4th quarter fiscal year 2016	4th quarter fiscal year 2016 to 1st quarter fiscal year 2017
Full-rate production decision				2nd quarter fiscal year 2017	Same
Full operating capability				3rd quarter fiscal year 2017	Same

Source: FCS Test and Evaluation Master Plan and FCS Program Office (data); GAO (analysis and presentation).

As shown in table 2, a key system-of-systems level test scheduled before the low-rate production decision is the Limited User Test 3 in 2012 to assess brigade combat team capabilities. This test will be the first large-scale FCS test that will include a majority of the developmental prototypes and a large operational unit and occurs only one year before the low-rate production decision. The Army is planning to have prototypes of all FCS systems available for testing prior to low-rate initial production, but these prototypes are not expected to be production-representative and may not be fully integrated. Whereas the testing of fully-integrated, production-representative prototypes demonstrates design maturity, this knowledge point will not be attained until after the low-rate production decision is made.

The IDA reported in 2007 that the Army's plan for testing and analyzing in one phase and then fixing and retesting in the next phase could cause

problems in FCS because the test and analysis half of one phase overlaps the development half of the next phase. The IDA pointed out that this means test results from one phase cannot easily be available for use in the next phase. It noted that the program's later phases are particularly at risk of failing to capture rework requirements identified by earlier experimentation and testing. It predicts that the compressed schedule of development and test events, together with dense schedule dependencies among program activities, will mean that any rework required will lead to a program-wide schedule slip. In anticipation of these and other related consequences, the IDA predicts that there needs to be at least one cycle of additional FCS test and evaluation beyond the current planned test sequence in order to resolve outstanding issues from previous, overlapping phases and complete development.

As mentioned earlier, a systems engineering assessment will be conducted on the FCS program for the 2009 milestone review. This assessment will be an important input for the 2009 review because it will include an evaluation of risks associated with the FCS acquisition strategy, test plan, and key complementary programs. It will also evaluate the program's system engineering plan for reasonable exit criteria associated with the critical design review and production readiness.

Production Commitments Are Planned to Be Made Early Despite Late Demonstration of FCS Capabilities

While the FCS low-rate production decision for the core FCS program is to be held in fiscal year 2013, in fact, production commitments are planned to begin in fiscal years 2008 and 2009 with production for the first of a series of three planned spin out efforts and the early versions of the NLOS-C vehicle. When considering these activities, along with long-lead and facilitization investments associated with the production of FCS core systems, a total of \$11.9 billion in production money will have been appropriated and another \$6.9 billion requested by 2013. Including development funds, \$39 billion will have been appropriated and another \$8 billion requested for FCS. As noted previously, key demonstrations of FCS capabilities will not yet have taken place. Also, in April 2007, the Army announced its intention to contract with the LSI for the low-rate production of the first 3 brigade combat teams of FCS systems—some 6 years in advance of the low-rate production decision—in addition to the production of the FCS spin out items and the early production of NLOS-C vehicles. In so doing, the Army departed from its pre-development phase philosophy of keeping the LSI focused on development versus production, ceding its option to contract directly with the producers of the individual FCS systems. This decision makes an already unusually close relationship

between the Army and the LSI even closer, and heightens the oversight challenges FCS presents.

Spin Out Procurement to Begin before Testing Completed

The Army has started a process to spin out selected FCS technologies and systems to current Army forces. The first spin out systems will be tested and evaluated in the coming year and a production decision is planned in 2009. However, the testing up to that point will feature some surrogate subsystems rather than the fully developed subsystems that would ultimately be deployed to current Army forces. The Army also has general plans for a second and third round of spin outs but, according to Army officials, has not funded them.

In 2004, the Army revised its acquisition strategy to bring selected technologies and systems to current forces via spin outs while development of the core FCS program is underway. This strategy provides for deployment of FCS capabilities to current forces through three spin out efforts. The first spin out has already started, the second is scheduled to start in 2010, and the third in 2012. Each spin out is to have its own production decision point. The Army expects these spin outs to incrementally field some capabilities to the current forces as well as provide opportunities to test, experiment, and learn for the FCS core program. In 2006, the Army established the Army Evaluation Task Force to use, evaluate, and train with the spin out capabilities. This unit also is expected to refine FCS doctrine and other matters.

Spin out 1 includes development, testing, procurement, and related installation and training activities necessary to integrate initial capabilities with 3 current force vehicles—the Abrams tank, the Bradley vehicle, and the High-Mobility Multipurpose Wheeled Vehicle—and to field unattended ground sensors and the Non-Line-of-Sight Launch System. Planned capabilities, added to these vehicles via modification kits, also include two radios from the JTRS, an integrated computer system, and early versions of the system-of-systems common operating environment and battle command software subsystems. The Army expects spin out 1 capabilities to address current force gaps in situational awareness, force protection, and lethality and, if found to have sufficient military utility, plans to start fielding them to operational units in fiscal year 2010. According to the Army, it has fully budgeted for developing and procuring these spin out 1 capabilities, after a go-ahead decision from the Defense Acquisition Board. Once approved by the board, the Army plans to begin procurement of long-lead production items for spin out 1 in fiscal year 2008. It estimates spending about \$178 million total on spin out 1 development in fiscal years

2008 to 2012 and approximately \$2.6 billion on spin out 1 procurement in fiscal years 2008 to 2013. Procurement of these items will continue for many years in that the Army plans to field them to all current force units.

The Army is now integrating the spin out capabilities with current force vehicles. These capabilities consist of hardware and software that are largely stand-alone systems, several of which were in development before the FCS program was initiated. For example, both the JTRS and unattended weapon system predate the start of FCS in 2003. Taken together, these spin out 1 capabilities serve as a starting point for FCS and represent only a fraction of the total capability that the Army plans for FCS to provide.

The Army plans to begin testing spin out 1 capabilities in fiscal year 2008 and finish testing them in fiscal year 2010. It anticipates an initial production decision on spin out 1 capabilities in January 2009. At this decision, the Army plans to request authorization to produce a limited quantity of production items for use as test assets for operational testing and for production ramp-up. Before the production decision, there are several major test events that help the Army Evaluation Task Force evaluate the contribution of spin out 1 capabilities. These tests include a technical field test in the spring of 2008 to verify technical aspects of the capabilities, a force development test and evaluation in the early summer of 2008 to validate requirements and training associated with the capabilities, and a limited user test in mid-summer 2008 to operationally test the capabilities. However, none of these tests will use the fully functional JTRS radios or associated software that is to be provided to the current forces at spin out 1 fielding. Instead, because the JTRS radios and their software will not be fully developed at that time, the Army plans to use engineering development versions of the radios for ground vehicles and surrogate non-JTRS hardware and software.

The Army believes that this test strategy mitigates risk and maintains that it will have the fully-capable JTRS radios and software for spin out 1 testing that is to be conducted shortly after the initial production decision. However, this approach is not without risk. First, as stated by Army officials, testing with surrogates will not necessarily provide quality measurements to gauge system performance. Second, as noted by the IDA, the Army may have to redesign if the fully developed and certified JTRS radios have different form, fit, function, and interoperability characteristics than expected. In short, the Army will be accepting sizable risks in deciding to produce the spin out capabilities before tests finish evaluating how well they can address current force capability gaps.

In addition to spin out 1, the Army also has plans for spin outs 2 and 3. However, those spin outs are less well-defined than spin out 1, and Army officials have stated that they are not yet funded. The capabilities planned for spin out 2, which is scheduled for the fiscal year 2010 to 2012 time frame, include upgraded versions of JTRS radios, an active protection system, and a mast-mounted sensor for the Stryker armored combat vehicle. Under spin out 3, which is planned for fiscal years 2012 to 2014, capabilities may include some FCS-developed small unmanned ground vehicles and unmanned airborne assets as well as the full FCS battle command capability.

NLOS-C Production Planned to Begin Soon at Congress's Direction

Since fiscal year 2003, the Army has been required by Congress to make future budgetary and programming plans to fully finance the NLOS-C in order field a self-propelled, indirect fire capability.¹³ Most recently, the Department of Defense Appropriations Act, 2008, required the Army to make plans to field the system by fiscal year 2010 and to deliver 8 NLOS-C prototypes by the end of calendar year 2008.¹⁴ These systems are to be in addition to those needed for developmental and operational testing.

The Army plans to begin procuring long-lead production items for the NLOS-C vehicle in 2008 to meet this requirement. The Army determined that a set of 18, a full battalion's worth, would be needed to meet the intent of the language. The Army plans to deliver six units per year in fiscal years 2010 through 2012. However, these early NLOS-C vehicles will not meet threshold FCS requirements and will not be operationally deployable without significant modification; rather, they will be used as training assets for the Army Evaluation Task Force.

The Army has not finalized plans for facilities in which to build the early NLOS-C vehicles; these decisions are expected to be made no later than the manned ground vehicles preliminary design review in fiscal year 2009. Initially, the Army will likely use the current facility in Lima, Ohio, for hull fabrication and chassis assembly of ground vehicles. The mission module structural fabrication and assembly for most manned ground vehicles will likely be done in a York, Pennsylvania, facility. According to a program official, ground has been broken on an additional facility in Elgin,

¹³ Department of Defense Appropriations Act, 2003, Pub. L. No. 107-248, § 8121 (2002), and similar provisions in subsequent defense appropriations acts.

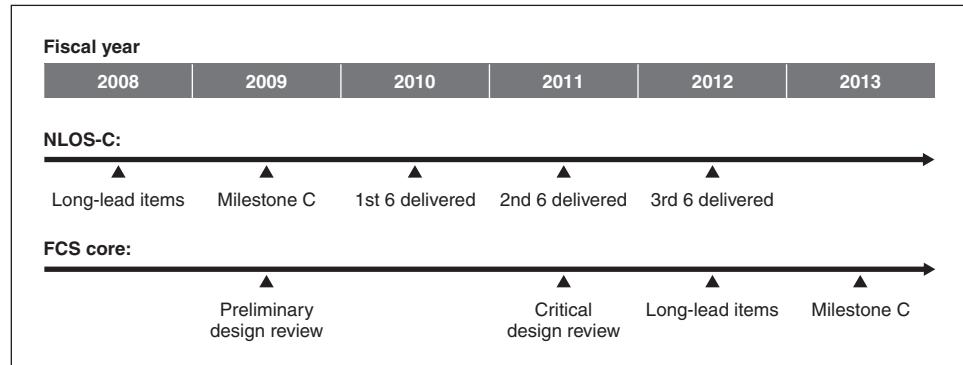
¹⁴ Pub. L. No. 110-116, § 8088 (2007).

Oklahoma, where NLOS-C mission module assembly is expected. The expected costs of these facilities and the process to approve and fund the building of the facilities are unclear at this point.

To meet the early fielding dates, the Army will begin early production of these NLOS-C vehicles with immature technologies and designs. Several key technologies, such as lightweight armor, the active protection system, and the JTRS radios will not be fully mature for several additional years. Much requirements work remains on the manned ground vehicles, including the NLOS-C, and software development is in its early stages. Design work on the manned ground vehicles also remains to be done, including work on the chassis and mission modules. Significant challenges involving integrating the technologies, software, and design will follow. To the extent that these aspects of the manned ground vehicles depart from the early production cannons, costly rework of the cannons may be necessary.

As seen in figure 6 below, this commitment to NLOS-C production comes 5 years before the Army plans to produce the core FCS program in 2013. Because of this, the early prototypes will most likely have to be hand-built because production facilities and processes and the necessary tooling will not be fully developed at that time.

Figure 6: NLOS-C versus Core FCS Procurement Schedule



Source: U.S. Army (data); GAO (analysis and presentation).

The Army is planning for a seamless transition between NLOS-C production and core FCS production. Beginning the production of NLOS-C vehicles 5 years before the start of FCS core production could create additional pressure to proceed with FCS core production. Advance procurement funding for the first full suite of FCS systems will begin in

fiscal year 2011, the budget for which will be presented to Congress in February 2010—less than a year after the milestone review and before the stability of the FCS design is assessed at the critical design review. By 2013, the Army will have already invested a total of \$11.9 billion in procurement, with another \$6.9 requested. Moreover, to the extent that beginning NLOS-C production in 2008 starts up the manned ground vehicle industrial base, it could create a future need to sustain the base. If FCS goes according to plan, FCS core production would begin as early NLOS-C production ends, with FCS core long lead items providing a transition. If decision makers were to consider delaying FCS core production because it was not ready, a gap could develop when early NLOS-C production ends. Sustaining the industrial base could then become an argument against an otherwise justified delay.

In December 2007, the Under Secretary of Defense for Acquisition, Technology, and Logistics took steps to keep the decisions on the NLOS-C early production separate from FCS core production. In approving procurement of long-lead items for the NLOS-C vehicles in 2008, the Under Secretary designated the 18 early prototypes as a separate, special interest program for which he will retain authority for making milestone decisions. The Under Secretary plans another decision in 2009 to approve the start of NLOS-C production and has put a cost limit of \$505.2 million (fiscal year 2003 dollars) on production. He also specified that specific requirements be met at that time, such as a capability production document, technology readiness assessment, test plan, independent estimate of costs, and an approved acquisition program baseline. This is a positive step in ensuring that the Army's efforts to meet congressional direction do not result in unfavorable consequences.

Army's Early Commitment to LSI for FCS Production Heightens Oversight Challenges

The Army's April 2007 decision to contract with the LSI for FCS production makes an already close relationship closer, represents a change from the Army's rationale prior to beginning development for using an LSI, and may further complicate oversight. As LSI, Boeing's role is multifaceted: it is a partner with the Army in developing requirements and defining the FCS solution; it is overseeing the development efforts of all of the individual system subcontractors, a role that will extend well beyond the 2013 production decision; it is responsible for developing two key software products—the system-of-systems common operating environment, the core of the FCS network, and the Warfighter Machine Interface; it is the prime contractor for the production of spin outs and the NLOS-C; and now it is to be responsible for the low-rate production of the first three combat brigades of FCS core systems.

The specific role the LSI will play in production of spin outs, NLOS-C, and FCS core production are unclear at this point. The contracts for long lead items for spin out 1 and NLOS-C have not been definitized yet and statements of work for the production contracts will be negotiated later. According to the program officials, Boeing will contract with the first tier subcontractors who will in turn contract with their own subcontractors. For example, the firms that are designing and developing and will physically manufacture NLOS-C are General Dynamics and British Aerospace. Similarly, the work that the LSI does on actual production of the FCS is likely to be small compared to the other hardware suppliers and assemblers. Thus, the production role of the LSI is likely to be largely in oversight of the first tier subcontractors.

From the outset of the program, the LSI was to focus its attention on development activities, which the Army judged to be beyond what it could directly handle. The Army believed that traditionally, contractors made much of their profit in production, not in research and development. Thus, the Army reasoned, the contractors are not as motivated by research and development as they are by production. Army leadership believed that by using an LSI that would not necessarily have to be retained for production, the Army could get the best effort from the contractor during the development phase while at the same time making the effort profitable for the contractor. The Army had always reserved the right to contract directly with the developers of the individual FCS systems for production. In 2005, the Army took steps to further bound the integrator role when it strengthened the organizational conflicts of interest clause in the contract to preclude the LSI from competing for any further subcontracts.

Nonetheless, the LSI's involvement in the production phase has been growing over time. The current LSI development contract for the core FCS systems extends almost 2 years beyond the 2013 production decision. The Army does not expect that the initial brigades outfitted by FCS will meet the upper range of its requirements, and has made the LSI responsible for planning future FCS enhancements during the production phase. The LSI is also responsible for defining and maintaining a growth strategy for integrating new technologies into the FCS brigade combat teams. Combined with a likely role in sustainment, which has not yet been fully defined, the LSI will remain indefinitely involved in the FCS program. It is also likely that the LSI will be used over the long term for data and configuration management, among other things.

The recent decision to commit to the LSI for the early production of FCS spin out items and NLOS-C vehicles as well as the initial low rate

production of FCS core systems is perhaps the final departure from the Army's effort to keep the contractor's focus solely on development. It is particularly significant given that it is 6 years in advance of the low-rate production decision and effectively cedes a key point of leverage—source selection—that the Army held. The Army justified its decision on the grounds that it is the most cost effective means of proceeding. The Army believes that Boeing's previous experience with FCS provides the company the unique management framework and expertise necessary to proceed. The Army also cites Boeing's common configuration management process and the ability to integrate systems-of-systems trade-offs and requirements changes holistically. While these may be legitimate advantages, they would not necessarily represent new discoveries on the part of the Army but rather natural advantages that would likely accrue to an incumbent system integrator. In addition, the Army's analysis that led up to the decision did not assess its originally stated option of the Army's contracting directly with the individual system developers for production, but rather focused on the much narrower question of whether it was feasible for any other contractor to perform the role of the LSI for the entire FCS program.

We have previously reported that the complex relationship between the Army and Boeing increases the burden of oversight and poses risks for the Army's ability to provide independent oversight over the long term.¹⁵ The relationship between the Army and Boeing broke new ground in its close, partner-like arrangement. It has advantages over an arms-length relationship but makes oversight more challenging. Specifically, we have noted that:

- The government can become increasingly vested in the results of shared decisions and runs the risk of being less able to provide oversight.
- The Army's performance, such as in developing critical technologies, may affect the LSI's ability to perform, a situation that can pose accountability problems.
- It may be difficult for the Army to separate its own performance from that of the LSI's when making decisions on how and whether to award fees.

¹⁵ GAO-07-380.

The Army's decision to commit to the LSI as the source for initial FCS production in 2013 makes the relationship even closer and more interdependent. Beyond the existing oversight challenges the relationship already posed, there is now an additional need to guard against the natural incentive of production from creating more pressure to proceed through development checkpoints prematurely. As we have previously reported, this is a burden that will need to be increasingly borne by the Office of the Secretary of Defense.

FCS Costs Likely to Be Higher Than Current Army Estimate

The Army's \$160.9 billion cost estimate for the FCS program is largely unchanged from last year's estimate despite a program adjustment that reduced the number of FCS systems from 18 to 14. This represents a reduction in the Army's buying power on FCS. Two independent cost assessments—from DOD's CAIG and the other from the IDA—are significantly higher than the Army's estimate. Both assessments estimate higher costs for software development, to which the recent increase in lines of code adds credence. Given the program's relative immaturity in terms of technology and requirements definition, there is not a firm foundation for a confident cost estimate. The Army maintains that when it becomes necessary, it will further reduce FCS content to keep development costs within available funding levels. As the Army begins a steep ramp-up of FCS production, FCS costs will compete with other Army funding priorities, such as the transition to modular organizations and recapitalizing the weapons and other assets that return from current operations. Together, the program's uncertain cost estimate and competing Army priorities make additional reductions in FCS scope and increases in cost likely.

Program Adjustment Reduces Scope, yet Costs Remain Largely the Same

Despite a major program adjustment that deleted 4 of the 18 platforms, extended the overall schedule by about 5 months, and further lengthened the production run, the Army's official cost estimate for the FCS program has only slightly decreased since last year. In inflated dollars, the program estimates the acquisition cost will be \$160.9 billion, down from last year's estimate of \$163.7 billion. The current estimate reflects the second major program restructuring in the program's history. The Army attributes the adjustment to (1) funding constraints in the fiscal year 2008 to 2013 program objective memorandum that made the previous configuration of the program unaffordable, (2) consecutive budget cuts by the Congress, and (3) the changing needs of the Army that incorporate lessons learned from ongoing conflicts in Iraq and Afghanistan. As of January 2008, the Army and LSI were in negotiations to implement these changes into the

development contract, and the dollar values of the specific changes were not yet available. For example, the cost savings from deleting four systems were offset by reducing annual procurement rates and extending the production schedule by 4 years.

The program adjustment may mean a reduction in capabilities of the FCS program. The impacts of the adjustment on the program are not yet fully known, but Army officials stated that the adjustment puts into doubt its ability to reach the full potential of the program. In 2003, the program was approved with a set of 14 core systems. Several systems were added when the program was restructured in 2004. Now, with this most recent adjustment, the program has once again been reduced to largely the same set of 14 systems, but in that time frame, the costs of the program increased by about 46 percent. This increasing cost, coupled with reductions in scope of the program, means a loss of buying power for the Army that may continue to the extent that costs continue to grow, forcing program officials to reduce more capabilities to stay within available funds.

Independent Assessments Indicate Potentially Higher Acquisition Costs

Two recent independent estimates, from IDA and the CAIG, suggest costs for the FCS program could be much higher than Army estimates. The Army's estimate; the independent assessment from IDA, which focuses on research and development costs; and the CAIG estimate are presented in table 3.

Table 3: Comparison of the Original Cost Estimate and Recent Cost Estimates for the FCS Program (in billions of dollars)

	May 2003 Army estimate	December 2005 Army estimate	May 2006 CAIG estimate	December 2006 Army estimate	April 2007 IDA assessment
Base-year 2003 Dollars					
Research, development, testing, and evaluation	\$18.1	\$26.4	\$31.8 - 44.0	\$25.1	Approx \$38.1
Procurement	\$59.1	\$92.8	\$118.7	\$87.5	N/A
Total	\$77.2	\$119.2	\$150.5 - 162.7	\$112.6	N/A
Then-year Dollars					
Research, development, testing, and evaluation	\$19.6	\$30.6	\$36.6 - 52.7	\$29.3	N/A
Procurement	\$71.8	\$133.1	\$166.7 - 181.2	\$131.6	N/A
Total	\$91.4	\$163.7	\$203.3 - 233.9	\$160.9	N/A

Source: U.S. Army, Office of the Secretary of Defense, IDA (data); GAO (analysis and presentation).

In its 2007 study, IDA estimated a potential \$13 billion in additional development costs above the Army's adjusted estimate because of unplanned software effort, additional costs related to rework during the operational test and evaluation phase of the program, and additional costs for system-of-systems integration, validation, and test after the program's critical design review. The study further identified significant additional cost risk, which it described as unquantifiable, because of incomplete technology maturation, critical dependency on complementary programs, necessary experimentation during FCS development, and the overall complexity and required synchronization of the FCS development activities. The IDA study did not assess likely procurement costs. The Army has stated that the IDA assessment does not give the Army credit for the risk mitigation offered by the integration phase approach and spin outs. The IDA expects an additional catch-up integration phase to be necessary, which increases work scope and would drive up development costs. Program officials said that the integration phase approach is a knowledge-based approach, but acknowledged that the overlapping schedules of the phases assumes success.

We reported last year that the CAIG's independent estimate indicated that FCS costs could ultimately range from \$203 billion to \$234 billion in inflated dollars. The CAIG estimate was based on additional procurement quantities that were never approved or funded. The CAIG's development estimate reflected several additional years and additional staffing beyond the Army's estimate to achieve initial operational capability. The difference in estimates is also attributable to the CAIG's assessment that the FCS software development would require more time and effort to complete than the Army had estimated. In fact, the Army recently indicated an increase in estimated software lines of code from 63 million to 95 million. The independent estimate also provided for additional risks regarding the availability of key systems to support the FCS network, such as the JTRS radios. Neither the Army nor the Defense Acquisition Board has accepted the independent estimate. Program officials stated last year that the independent cost estimate of research and development costs was too high because it was too conservative regarding risks.

In 2003, the CAIG's initial independent estimate for the program was \$101.1 billion in acquisition costs, versus the Army's estimate of \$77.2 billion in base year 2003 dollars. When the program began, the estimates were based on an FCS system-of-systems including 14 platforms with an additional four platforms deferred. The 2004 restructure brought back the deferred systems for a total of 18. But, the recent program adjustment once again deferred essentially the same set of platforms. The current

configuration is 14 systems, and the Army's cost estimate of \$112.6 billion in base year 2003 dollars is comparable to the CAIG's original estimate for the same number of FCS systems. The Army's estimate has thus increased about 46 percent over the course of 4 years for essentially the same set of platforms, while some capabilities, such as the transport requirements for manned ground vehicles, have been modified over that time frame.

The Army has not accepted either of the independent estimates on the grounds that the CAIG and IDA estimates include additional work scope, particularly in the later years of the development phase. Program officials told us that the Army cannot fund additional work that is not currently in its scope. The CAIG and IDA both use historical growth factors in their estimates, based on the results of previous programs. It is reasonable to use such growth factors, based on our own analysis of weapon systems and the low level of knowledge attained on the FCS program at this time. Given the different approaches from the Army and the independent estimators, it is likely the CAIG and the Army will still differ in their estimates when the CAIG prepares its independent estimate for the 2009 program review. Army officials have said they will not increase program cost estimates to fall in line with independent estimates, but will instead consider trading away requirements or changing their concept of operations to keep FCS development costs within available funding levels. The Army and LSI are currently conducting analyses to determine which requirements and capabilities can be discarded with the least impact to the program. The FCS contract also contains a clause on program generated adjustments. This allows the LSI to identify a prioritized list of capabilities in advance that can be partially or completely deleted should the need arise. The money budgeted for them can then be redirected to new work scope or to offset a cost overrun. Should the higher cost estimates prove correct, the Army will have to make significant changes in planned capabilities to absorb the higher program costs.

FCS Still Lacks Solid Knowledge Base from Which to Make Confident Cost Estimates

Cost estimates for any program are limited by the level of product knowledge available. We have previously reported that the Army's estimates are limited by the low level of knowledge in the FCS program today. The current FCS estimates do not have a base of mature technologies and well-defined system-level requirements. There have been few demonstrations of FCS capabilities to date, and the set of complementary programs that the FCS program will rely on to function properly is still uncertain. Therefore, the Army must make significant assumptions about how knowledge will develop. As experience has

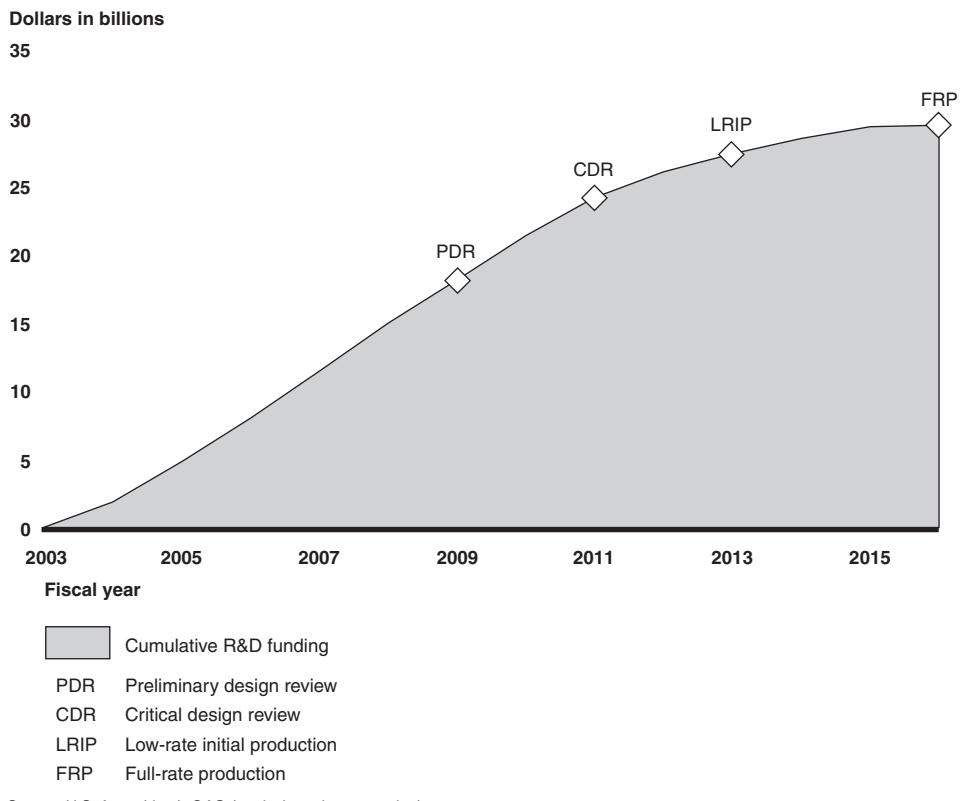
shown, in many DOD weapon systems, assumptions generally prove optimistic and result in underestimated costs.

One way to reduce the probability of unbudgeted cost growth is to present a confidence level for a cost estimate based on risk and uncertainty analyses. Such analyses entail testing the sensitivity of costs to changes in input values and key assumptions. While confidence levels have limitations in that they are dependent on the assumptions made in calculating them, their use is recognized as a best practice. In an effort to better ensure realism in DOD budgets, a 2006 panel on acquisition reform established by the Deputy Secretary of Defense recommended that program budgets be set at a specific confidence level.¹⁶ To date, the Army has not calculated a confidence level for its FCS cost estimate. FCS program officials maintain that while they would like to explore this area, confidence levels are difficult to do because the program's budget frequently changes and requirements are undefined. On the other hand, this is the kind of variability that a confidence level analysis attempts to capture.

As it is currently structured, the Army is planning to make substantial financial investments in the FCS program before key knowledge is gained on requirements, technologies, system designs, and system performance. Figure 7 shows the cumulative funding, as reported in the program's current cost estimate, and the timing of the program's key events. Appendix V has a year-by-year breakdown of FCS research and development funding and key events.

¹⁶ Defense Acquisition Performance Assessment Panel, *Defense Acquisition Performance Assessment Report*, (Washington, D.C.: January 2006).

Figure 7: Cumulative FCS Research and Development Funding and Key Events



Source: U.S. Army (data); GAO (analysis and presentation).

As indicated in figure 7, by the time of the preliminary design review and the go/no-go decision in 2009, the Army will have spent over \$18 billion—60 percent—of its development budget. At that point, the program should have matured most of the critical technologies to TRL 6, and the definition of system-level requirements should be nearing completion. This is the level of knowledge the program should have reached in 2003 before being approved for development start, according to best practices and the approach preferred by DOD in its acquisition policies. Yet, significantly expensive work, such as building and testing prototypes, remains ahead.

As reported by the CAIG and IDA, historical experience suggests FCS costs will grow higher, possibly significantly, beyond the Army's current estimate. Our previous work has shown that development costs for the programs with mature technologies increased by a modest average of 4.8 percent over the first full estimate, whereas the development costs for the programs with immature technologies increased by a much higher average

of 34.9 percent. Similarly, program acquisition unit costs for the programs with the most mature technologies increased by less than 1 percent, whereas the programs that started development with immature technologies experienced an average program acquisition unit cost increase of nearly 27 percent over the first full estimate. Our work also showed that most development cost growth occurred after the critical design review. Specifically, of the 28.3 percent cost growth that weapon systems average in development, 19.7 percent occurs after the critical design review. An example of a program that did not allow enough time in development and that is now dealing with the results is the Marine Corps' Expeditionary Fighting Vehicle. We reported in May 2006 that this program has seen a 45 percent increase in acquisition cost alongside reductions in key performance parameters and schedule delays—a major reduction in buying power.¹⁷ These effects are attributable to the fact that the program did not allow enough time in system development and demonstration to fully design and demonstrate the capabilities of the program before the decision to begin building prototypes.

Army Efforts to Control Cost Focus on Scope Reductions

The Army is attempting to manage the growing cost of the FCS. It has said that the Army will not exceed the cost ceiling of the development contract, but as a result, it may have to modify, reduce, or delete lower priority FCS requirements. Also, the Army is focusing on reducing the projected average unit production cost of the brigade combat teams, which is currently projected to exceed the amount at which each brigade combat team is budgeted. As a result of the program adjustment, the Army has re-established a lower average unit production cost target. Prior to the adjustment, the Army had established a glide path for cost reduction, but had been struggling to meet the goals in some areas, particularly with the manned ground vehicles. The Army has developed affordability initiatives to help it reach the targets, but their effectiveness may not be realized for several years.

The Army and the LSI monitor the performance of the FCS program through an earned value management system, which provides information on the technical, schedule, and cost performance of the program. As it proceeds, the Army and LSI can use the information gleaned from the

¹⁷ GAO, *Defense Acquisitions: The Expeditionary Fighting Vehicle Encountered Difficulties in Design Demonstration and Faces Future Risks*, GAO-06-349 (Washington, D.C.: May 1, 2006).

earned value management system to make informed program decisions and correct potential problems early. According to recent earned value data, (which does not currently take into account the scope reduction of four systems) the FCS program is currently tracking fairly closely with cost and schedule expectations that were revised in 2004, although some variances are beginning to show in key areas such as the Non-Line-of-Sight Launch System. However, it is too early in the program for the data at this point to be conclusive. In the case of the FCS, when the program restructured its scope in 2004, the earned value data up to that point was rebaselined. And, because of the recent program adjustment, the future work on the program is being replanned. As a result, the earned value data at this point provides little insight into the potential future performance of the program and the extent of the challenges the Army still faces with FCS.

Army Begins Steep Ramp Up of FCS Procurement Funding in 2008

The FCS program plans to begin spending procurement money in fiscal year 2008 for long lead items for the spin outs and for the NLOS-C. FCS procurement funding then ramps up very quickly, as can be seen in table 4. By the time of the low-rate initial production decision for the core program in 2013, the Army expects that a total of \$39.1 billion will have been appropriated and another \$8 billion requested for FCS. \$11.9 billion of the appropriated funds and \$6.9 billion of the requested funds will be for production costs. This money will include spin out production, early NLOS-C production, and long lead and facilitization for FCS core production. About \$500 million (fiscal year 2003 dollars) of this will be designated for NLOS-C early production through fiscal year 2012.

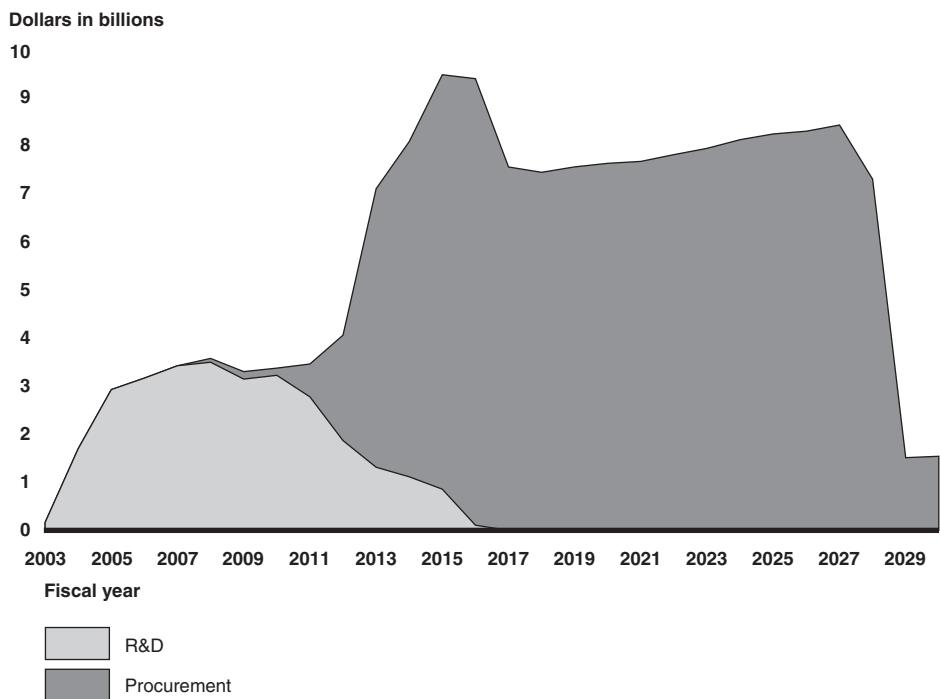
Table 4: FCS Procurement Funding through 2013

Fiscal year (dollars in millions)	2008	2009	2010	2011	2012	2013	TOTAL
Core program	79.5	155.8	149.4	683.8	2194.6	5795.3	9058.4
Spin outs	20.1	172.7	373.8	557.1	779.7	958.1	2861.4
Total	99.6	328.5	523.2	1240.9	2974.3	6753.3	11919.8

Source: U.S. Army (data); GAO (analysis and presentation).

As indicated in figure 8 below, the increasing budget demands for FCS production are occurring when FCS development costs are still high and, per independent estimates, may be higher yet.

Figure 8: FCS Research and Development and Procurement Funding Profile from Fiscal Year 2003 through Fiscal Year 2030



Source: U.S. Army (data); GAO (analysis and presentation).

The Army will have to balance its needs for the FCS program with competing demands from within the Army and DOD, including the Army's efforts to change its division-based force structure to smaller, more numerous brigade formations. These efforts have proven significantly more costly and time consuming than originally planned. The Army will also have to fully define the content of spin outs 2 and 3 and secure funding for their full costs, which could be substantial. Additional reductions in FCS scope and capabilities may become necessary if the high budgets needed cannot be sustained. By the time of the FCS milestone review in 2009, the fiscal year 2010 Army budget will be under consideration by the Congress, and the fiscal year 2010 to 2015 future years defense program will be available. This program will include the first few years of FCS production, at the annual rate of 1 brigade combat team per year, and the procurement of spin outs 2 and 3. As such, it should provide insights as to whether the Army can reasonably fund FCS and its other priorities.

Conclusions

The 2009 milestone review will be perhaps the definitive decision on FCS's future. For several reasons, the decision bears the responsibility of both a commitment to continued development and to production. The Army's strategy for FCS—with technologies still immature, insufficient testing of system prototypes before low-rate production, and a high likelihood of cost increases—has never abided by DOD policy and in 2013 is likely to present decision makers with a partially developed and largely undemonstrated system for production. If significant problems have to be corrected during production, the costs could be prohibitive, thus putting the Army's modernization plan in jeopardy. It is therefore essential at the 2009 decision that the FCS business case be demonstrated against clear criteria—both as to what performance it can deliver and the soundness of its remaining schedule—versus being assessed on potentialities. With such large sums already invested, early production having begun in 2008, and the late development and demonstration of the FCS capability, decision makers in 2013 will be in a very difficult position under the current strategy.

The deficiencies we cite in this report in areas such as requirements and technology are not criticisms of progress in the sense that things should have gone smoother or faster. At issue, rather, is the misalignment of the program's normal progress with the events used to manage and make decisions on such acquisitions—key decisions are made well before requisite knowledge is available. The decisions in 2009 will provide an opportunity to realign the progress of knowledge in FCS with events such as the critical design review and tests of prototypes before the production decision. The 2009 decision point may also be the government's last realistic opportunity to safeguard its ability to change course on FCS, should that be warranted. The first decision, as we see it, will have to involve whether FCS's capabilities have been demonstrated to be both technically feasible and militarily worthwhile. If they have not, then DOD and the Army will need to have viable alternatives to fielding the FCS capability as currently envisioned. Depending on the results of the first decision, the second decision is to determine how to structure the remainder of the FCS program so that it attains high levels of knowledge before key commitments.

Other aspects of the FCS program warrant attention that should not wait until the 2009 decision. Primary among these is the Army's decision to extend the role of the LSI into FCS production. This is a decision that will necessarily heighten the role the Office of the Secretary of Defense will have to play in overseeing the program and departs from the Army's philosophy of having the LSI focus on development without the competing

demands and interests that production poses. A second aspect of the program warranting attention is the Army's approach to spin outs. It will be important for the Army to clearly demonstrate the military utility of the spin outs to current Army forces based on testing high-fidelity, production-representative prototypes, before a commitment is made to low-rate production. This is not the current plan, as the Army plans to use some surrogate equipment in the testing that will support the production decision for spin out 1. Finally, it is important that the production investments in the spin outs and NLOS-C do not create undue momentum for production of FCS core systems. As noted above, commitment to production of the FCS's core systems must be predicated on attaining high levels of knowledge, consistent with DOD policy. The Under Secretary of Defense's recent decision to break out early NLOS-C production as a separate acquisition program goes a long way to meet congressional direction on NLOS-C while mitigating the consequences for the rest of the FCS program. This is an issue that will need sustained attention.

Recommendations for Executive Action

To ensure that the 2009 FCS milestone review is positioned to be both well-informed and transparent, we recommend that the Secretary of Defense establish objective and quantitative criteria that the FCS program will have to meet in order to justify its continuation and gain approval for the remainder of its acquisition strategy.¹⁸ The criteria should be set by at least July 30, 2008, so as to be prescriptive, and should be consistent with DOD acquisition policy and best practices. At a minimum, the criteria should include

- the completion of the definition of all FCS requirements including those for the information network;
- the demonstration that preliminary designs meet FCS requirements;
- the maturation of all critical technologies;
- the synchronization of FCS with all essential complementary programs;

¹⁸ In our March 2007 report, we recommended that the Secretary of Defense establish criteria to evaluate the FCS program at that decision. Although DOD concurred with our recommendations and outlined how the Defense Acquisition Board's review of FCS in 2009 would be informed by a number of critical assessments and analyses, it did not specifically respond to our recommended criteria that it will use to evaluate the FCS program.

-
- a sound and executable acquisition strategy, including
 - the synchronization of the development and demonstration of the FCS information network with the development and demonstration of other FCS elements,
 - a realistic path forward to critical design review,
 - a thorough and robust test and evaluation plan, and
 - a realistic path forward to production process maturity before the start of production;
 - development and production cost estimates that (1) have a specified confidence level and (2) are reconciled with independent estimates; and
 - assurance that the Army can properly fund, over the long term, the FCS program of record.

We recommend that the Secretary of Defense, in advance of the 2009 milestone review, identify viable alternatives to FCS as currently structured that can be considered in the event that FCS does not measure up to the criteria set for the review. As we have previously reported, an alternative need not be a rival to the FCS, but rather the next best solution that can be adopted if FCS is not able to deliver the needed capabilities. For example, an alternative need not represent a choice between FCS and the current force, but could include fielding a subset of FCS, such as a class of vehicles, if they perform as needed and provide a militarily worthwhile capability.

Finally, we recommend that the Secretary of Defense (1) closely examine the oversight implications of the Army's decision to contract with the LSI for early production of FCS spin outs, NLOS-C, and low-rate production for the core FCS program; (2) take steps to mitigate the risks of the Army's decisions, including the consideration of the full range of alternatives for contracting for production; and (3) evaluate alternatives to the LSI for long-term sustainment support of the FCS system of systems.

Agency Comments and Our Evaluation

DOD concurred with our recommendations and stated that criteria for the 2009 FCS Defense Acquisition Board review, aligned with the FCS's preliminary design review, will be reviewed and finalized at the 2008 FCS Defense Acquisition Board review. For its 2009 review, the Defense Acquisition Board expects the Army to provide evidence of stable requirements, verification that the preliminary design can meet those requirements, evidence of mature technologies, alignment of essential complementary systems, an executable acquisition strategy, a low-risk cost estimate, and an affordability assessment. The results of the analyses and assessments planned to support the 2009 review will inform DOD's acquisition and budget decisions for FCS. These are positive steps toward informing the 2009 Defense Acquisition Board review. For example, the expectation that FCS will have mature critical technologies is a step beyond simply conducting an independent assessment of technology maturity. Likewise, aligning essential complementary systems would demonstrate measurable progress more than simply updating status and issues for complementary systems.

DOD states that an analysis of alternatives will inform the 2009 FCS review. It is important that such an analysis go beyond whether FCS is the preferred alternative, and assess alternatives to FCS in the event the Defense Acquisition Board determines the FCS program of record is not executable or affordable. Such alternatives would not necessarily represent a choice between competing solutions, but may, for example, include a subset of FCS systems augmenting current forces.

Regarding our recommendations related to oversight, DOD stated that it would evaluate FCS production contracting approaches and risks, as well as alternatives to the LSI for long-term sustainment support. DOD is silent on the expansion of the LSI's role into core FCS production and cites its reliance on Army analyses and risk assessments. Yet, the Army has already indicated its intent to go forward with its plans for production, including contracting with the LSI, pending approval to do so. It is essential that the Office of the Secretary of Defense perform its own analyses and assessments, so that it may arrive at its own conclusions. In particular, the Office must evaluate the advantages and risks of the LSI's expanded production role with regard to the potentially greater burden of oversight it will likely bear as a consequence.

Finally, the department maintains that GAO's definition of testing requirements to support the low-rate initial production decision is more in line with the requirements for Initial Operational Test and Evaluation, which occurs with low-rate production assets and informs the full-rate

production decision. The testing standards we apply reflect the best practice of having production-representative prototypes tested prior to a low-rate production decision. This approach demonstrates the prototypes' performance and reliability as well as manufacturing processes—in short, that the product is ready to be manufactured within cost, schedule, and quality goals.

We received other technical comments from DOD, which have been addressed in the report, as appropriate.

We are sending copies of this report to the Secretary of Defense; the Secretary of the Army; and the Director, Office of Management and Budget. Copies will also be made available at no charge on the GAO Web site at <http://www.gao.gov>.

Please contact me on (202) 512-4841 if you or your staff has any questions concerning this report. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Other contributors to this report were Assistant Director William R. Graveline, Noah B. Bleicher, Martin G. Campbell, Tana M. Davis, Marcus C. Ferguson, and Carrie R. Wilson.



Paul L. Francis
Director
Acquisition and Sourcing Management

List of Committees

The Honorable Carl Levin
Chairman
The Honorable John McCain
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Daniel K. Inouye
Chairman
The Honorable Ted Stevens
Ranking Member
Subcommittee on Defense
Committee on Appropriations
United States Senate

The Honorable Ike Skelton
Chairman
The Honorable Duncan L. Hunter
Ranking Member
Committee on Armed Services
House of Representatives

The Honorable John P. Murtha, Jr.
Chairman
The Honorable C. W. (Bill) Young
Ranking Member
Subcommittee on Defense
Committee on Appropriations
House of Representatives

Appendix I: Scope and Methodology

To develop the information on the Future Combat System program that we used to assess (1) how the definition, development, and demonstration of FCS capabilities is proceeding, particularly in light of the go/no-go decision scheduled for 2009; (2) the Army's plans for making production commitments for FCS and any risks relative to the completion of development; and (3) the estimated costs for developing and producing FCS and risks the Army faces in both meeting the estimate and providing commensurate funding, we interviewed officials at the Office of the Under Secretary of Defense (Acquisition, Technology, and Logistics); the Secretary of Defense's Cost Analysis Improvement Group; the Institute for Defense Analyses; the Army's Training and Doctrine Command; the Future Force Integration Directorate; the Army Evaluation Task Force; the Army Test and Evaluation Command; the Director of the Combined Test Organization; the Program Manager for the Future Combat System (Brigade Combat Team); the Future Combat System LSI; and LSI One Team Partners.

We reviewed many Army and DOD documents, including the *Future Combat System's Operational Requirements Document*, the *Acquisition Strategy Report*, the *Selected Acquisition Report*, the *Test and Evaluation Master Plan*, critical technology assessments and technology risk mitigation plans, and modeling and simulation results.

We attended the Board of Directors Reviews, the Engineering Maturity 1 event, and multiple system demonstrations. In our assessment of the FCS, we used the knowledge based acquisition practices drawn from our large body of past work as well as DOD's acquisition policy and the experiences of other programs.

We certify that officials from DOD and the Army have provided us access to sufficient information to make informed judgments on the matters in this report. We discussed the issues presented in this report with officials from the Army and the Secretary of Defense and made several changes as a result. We performed our review from March 2007 to March 2008 in accordance with generally accepted auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Comments from the Department of Defense



OFFICE OF THE UNDER SECRETARY OF DEFENSE
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

FEB 28 2008

ACQUISITION,
TECHNOLOGY
AND LOGISTICS

Mr. Paul L. Francis
Director, Acquisition and Sourcing Management
U.S. Government Accountability Office
441 G Street, N.W.
Washington, DC 20548

Dear Mr. Francis:

This is the Department of Defense (DoD) response to the GAO draft report, "DEFENSE ACQUISITIONS: 2009 Is a Critical Juncture for the Army's Future Combat system," dated January 31, 2008 (GAO Code 120656/GAO-08-408).

The report recommends that the Secretary of Defense establish criteria for the Future Combat System (FCS) program to meet for approval at the 2009 review for continuation of the FCS acquisition strategy. The GAO recommended the Secretary of Defense identify viable alternatives to the FCS program as currently structured. Additionally, the GAO recommended examination of the alternatives for FCS production and sustainment.

The Department concurs with the GAO recommendations and our comments are enclosed. A technical comment of note is the GAO's definition of testing requirements to support the low-rate initial production decision is more in line with the requirements for Initial Operational Test and Evaluation, which occurs with low-rate production assets and informs the full rate production decision. Detailed technical comments were provided separately.

The Army's transformation effort, and in particular, the FCS program requires a disciplined, yet agile, acquisition construct. The FCS acquisition strategy includes periodic acquisition reviews by the Department, including a Defense Acquisition Board review, subsequent to the FCS preliminary design review in 2009.

Sincerely,

A handwritten signature in black ink, appearing to read "David G. Ahern".

David G. Ahern
Director
Portfolio Systems Acquisition

Enclosure:
As stated



**GAO DRAFT REPORT DATED JANUARY 31, 2008
GAO-08-408 (GAO CODE 120656)**

**"DEFENSE ACQUISITIONS: 2009 IS A CRITICAL JUNCTURE FOR
THE ARMY'S FUTURE COMBAT SYSTEM"**

**DEPARTMENT OF DEFENSE COMMENTS
TO THE GAO RECOMMENDATIONS**

RECOMMENDATION 1: The GAO recommended that the Secretary of Defense establish objective and quantitative criteria that the Future Combat System (FCS) program will have to meet in order to justify its continuation and gain approval for the remainder of its acquisition strategy. At a minimum the criteria should include:

- the completion of the definition of all FCS requirements including those for the information network;
- the demonstration that preliminary designs meet FCS requirements;
- the maturation of all critical technologies;
- the synchronization of FCS with all essential complementary programs;
- a sound and executable acquisition strategy, including
 - the synchronization of the development and demonstration of the FCS information network with the development and demonstration of other FCS elements,
 - a realistic path forward to critical design review,
 - a thorough and robust test and evaluation plan, and
 - a realistic path forward to production process maturity before the start of production;
- development and production cost estimates, that (1) have a specified confidence level, and (2) are reconciled with independent estimates; and
- assurance that the Army can properly fund, over the long term, the FCS program of record. (p. 49/GAO Draft Report)

DOD RESPONSE: Concur. Criteria for the 2009 FCS Defense Acquisition Board (DAB), aligned with the program's Preliminary Design Review, will be reviewed and finalized at the FCS DAB planned for later in 2008. The expectations for the 2009 FCS DAB include stable requirements, verification that the preliminary design can meet those requirements, mature critical technologies, aligning of the essential complementary systems, an executable acquisition strategy, a low-risk cost estimate, and an affordability assessment. The Department's FCS acquisition and budget decisions will be based on the results of the analyses and assessments planned to support the 2009 DAB review.

RECOMMENDATION 2: The GAO recommended that the Secretary of Defense, in advance of the 2009 milestone review, identify viable alternatives to FCS as currently structured that can be considered in the event that FCS does not measure up to the criteria set for the review.

DOD RESPONSE: Concur. An analysis of alternatives will inform the 2009 FCS review.

RECOMMENDATION 3: The GAO recommended that the Secretary of Defense closely examine the oversight implications of the Army's decision to contract with the Lead System Integrator (LSI) for early production of FCS spin outs, Non-Line-of Sight Cannon (NLOS-C), and low-rate production for the core FCS program.

DOD RESPONSE: Concur. The Department has separated the Congressionally mandated production of NLOS-C Special Interest vehicles from the FCS acquisition. The FCS spin-out production is currently authorized only for limited long-lead for a small subset of FCS capability, specifically the initial increments of the unattended ground sensors, the NLOS-Launch System, and integrated computer system for the current force brigades. Production contract approaches and risks will be examined in support of the Spin-Out 1 Milestone C decision.

RECOMMENDATION 4: The GAO recommended that the Secretary of Defense take steps to mitigate the risks of the Army's decisions, including the consideration of the full range of alternatives for contracting for production.

DOD RESPONSE: Concur. The Army will provide a risk assessment of production alternatives in support of the update to the FCS acquisition strategy. The Defense Acquisition Board and the Milestone Decision Authority address risks at the annual FCS program reviews.

RECOMMENDATION 5: The GAO recommended that the Secretary of Defense evaluate alternatives to the LSI for long-term sustainment support of the FCS system-of-systems.

DOD RESPONSE: Concur. The evaluation and analysis of alternative support and sustainment options for FCS brigades is a component of the program's product support strategy. This, in conjunction with the program's Core Logistics Analysis/Source of Repair Analysis, will inform program decisions throughout the acquisition life cycle.

Appendix III: Technology Readiness Levels

Technology Readiness Levels (TRL) are measures pioneered by the National Aeronautics and Space Administration and adopted by DOD to determine whether technologies were sufficiently mature to be incorporated into a weapon system. Our prior work has found TRLs to be a valuable decision-making tool because they can presage the likely consequences of incorporating a technology at a given level of maturity into a product development. The maturity level of a technology can range from paper studies (level 1), to prototypes that can be tested in a realistic environment (TRL 7), to an actual system that has proven itself in mission operations (level 9). According to DOD acquisition policy, a technology should have been demonstrated in a relevant environment (TRL 6) or, preferably, in an operational environment (TRL 7) to be considered mature enough to use for product development. Best practices of leading commercial firms and successful DOD programs have shown that critical technologies should be mature to at least a TRL 7 before the start of product development.

Technology readiness level (TRL)	Description	Hardware and software	Demonstration environment
1. Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties	None (paper studies and analysis)	None
2. Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative, and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.	None (paper studies and analysis)	None
3. Analytical and experimental critical function and/or characteristic proof of concept	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	Analytical studies and demonstration of non-scale individual components (pieces of subsystem).	Lab
4. Component and/or breadboard. Validation in laboratory environment	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in a laboratory.	Low-fidelity breadboard. Integration of non-scale components to show pieces will work together. Not fully functional or form or fit but representative of technically feasible approach suitable for flight articles.	Lab
5. Component and/or breadboard validation in	Fidelity of breadboard technology increases significantly. The basic technological	High-fidelity breadboard. Functionally equivalent but not	Lab demonstrating functionality but not

Appendix III: Technology Readiness Levels

Technology readiness level (TRL)	Description	Hardware and software	Demonstration environment
relevant environment	components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include “high fidelity” laboratory Integration of components.	necessarily form and/or fit (size, weight, materials, etc.). Should be approaching appropriate scale. May include integration of several components with reasonably realistic support elements/subsystems to demonstrate functionality.	form and fit. May include flight demonstrating breadboard in surrogate aircraft. Technology ready for detailed design studies.
6. System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology’s demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.	Prototype—Should be very close to form, fit, and function. Probably includes the integration of many new components and realistic supporting elements/subsystems if needed to demonstrate full functionality of the subsystem.	High-fidelity lab demonstration or limited/restricted flight demonstration for a relevant environment. Integration of technology is well defined.
7. System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.	Prototype. Should be form, fit, and function integrated with other key supporting elements/subsystems to demonstrate full functionality of subsystem.	Flight demonstration in representative operational environment such as flying test bed or demonstrator aircraft. Technology is well substantiated with test data.
8. Actual system completed and “flight qualified” through test and demonstration	Technology has been proved to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.	Flight-qualified hardware	Developmental test and evaluation in the actual system application
9. Actual system “flight proven” through successful mission operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last “bug fixing” aspects of true system development. Examples include using the system under operational mission conditions.	Actual system in final form	Operational test and evaluation in operational mission conditions

Source: GAO analysis of National Aeronautics and Space Administration data.

Appendix IV: FCS Critical Technology Ratings and Projections for Achieving TRL 6

FCS Critical Technologies		2006 TRL Rating	2006 TRL 6 Projection	2007 TRL Rating	2007 TRL 6 Projection
Joint Interoperability	Software Programmable Radio				
	1 JTRS Cluster 1	6	N/A	6	N/A
	2 JTRS Cluster 5	6	N/A	6	N/A
	3 WIN-T	6	N/A	5	2008
	Interface and Information Exchange				
	4 Army, Joint, Multinational Interface	6	N/A	6	N/A
	5 WIN-T Strategic Communication	6	N/A	5	2008
	Security Systems and Algorithms				
	6 Cross Domain Guarding Solution	6	N/A	6	N/A
	7 Intrusion Detection—IP Network	4	2008	5	2008
Networked Battle Command	8 Intrusion Detection—Waveform	4	2007	6	N/A
	Mobile Ad Hoc Networking Protocols				
	9	6	N/A	6	N/A
	Quality of Service Algorithms				
	10	5	2008	5	2008
	Unmanned Systems Relay				
	11	N/R	N/A	N/R	N/A
	Wideband Waveforms				
	12 Wideband Waveform—JTRS	6	N/A	6	N/A
	13 Wideband Waveform—SRW	6	N/A	6	N/A
	Advanced Man-Machine Interfaces				
	14	6	N/A	6	N/A
	Multi-Spectral Sensors and Seekers				
	15	6	N/A	6	N/A
	Decision Aids/Intelligent Agents				
	16	6	N/A	6	N/A
	Combat Identification				
Networked Lethality	17 Air (Rotary Wing/UAV)—to—Ground	6	N/A	6	N/A
	18 Air (Fixed Wing)—to—Ground (Interim/Robust Solutions)	N/R	N/A	N/R	N/A
	19 Ground—to—Ground (Mounted)	N/R	N/A	N/R	N/A
	20 Ground—to—Air (Mounted)	6	N/A	6	N/A
	21 Ground—to—Soldier	N/R	N/A	N/R	N/A
	Rapid Battlespace Deconfliction				
	22	5	2008	5	2008
	Sensor/Data Fusion and Data Compression Algorithms				
	23 Distributed Fusion Management	4	2008	5	2008
	24 Level 1 Fusion Engine	6	N/A	6	N/A
	25 Data Compression Algorithms	6	N/A	6	N/A
Dynamic Sensor—Shooter Pairing Algorithms and Fire Control	26	6	N/A	6	N/A
LOS/BLOS/NLOS Precision Munitions Terminal Guidance	27 PGMM Precision Munitions	6	N/A	N/R	N/A

**Appendix IV: FCS Critical
Technology Ratings and
Projections for Achieving TRL 6**

FCS Critical Technologies		2006 TRL Rating	2006 TRL 6 Projection	2007 TRL Rating	2007 TRL 6 Projection
28	MRM Precision Munitions	6	N/A	6	N/A
29	Excalibur Precision Munitions	6	N/A	7	N/A
30	NLOS-LS	6	N/A	6	N/A
Aided/Automatic Target Recognition					
31	Aided Target Recognition for RSTA	5	2008	5	2008
32	NLOS-LS ATR for Seekers	6	N/A	6	N/A
33	Recoil Management and Lightweight Components	6	N/A	6	N/A
34	Distributed Collaboration of Manned/Unmanned Platforms	6	N/A	6	N/A
35	Rapid Battle Damage Assessment	N/R	N/A	N/R	N/A
Transportability					
Sustainability / Reliability	High-Power Density/Fuel-Efficient Propulsion				
	36 High-Power Density Engine	6	N/A	6	N/A
	37 Fuel-Efficient Hybrid-Electric Engine	6	N/A	6	N/A
	38 Embedded Predictive Logistics Sensors and Algorithms	N/R	N/A	N/R	N/A
	39 Water Generation and Purification	N/R	N/A	N/R	N/A
Training	40 Lightweight Heavy Fuel Engine	5	2006	5	2008
	41 Computer Generated Forces	6	N/A	6	N/A
	42 Tactical Engagement Simulation	5	2008	6	N/A
Survivability	Active Protection System				
	43 Active Protection System	6	N/A	5	2008
	44 Threat Warning System	4	2009	4	2010
	45 Signature Management	6	N/A	6	N/A
	46 Lightweight Hull and Vehicle Armor	5	2008	5	2008
	47 Health Monitoring and Casualty Care Interventions	7	N/A	7	N/A
	48 Power Distribution and Control	6	N/A	N/R	N/A
	Advanced Countermine Technology				
	49 Mine Detection	6	N/A	6	N/A
	50 Mine Neutralization	6	N/A	6	N/A
Class 1 UAV Propulsion Technology	51 Efficient Resource Allocation	N/R	N/A	N/R	N/A
	52 Protection	5	2008	5	2008
	53 High-Density Packaged Power	6	N/A	6	N/A
	Ducted Fan	6	N/A	6	N/A

Source: U.S. Army (data); GAO (analysis and presentation).

Note: N/A = Not Applicable; N/R = Not Rated

Appendix V: Annual and Cumulative FCS Research and Development Funding and Planned Events and Achievements

Fiscal year	Percentage of funding spent to date	Annual research, development, testing, and evaluation funding (in millions of dollars)	Cumulative research, development, testing, and evaluation funding (in millions of dollars)	Planned events and achievements
2003	0.6	165.2	165.2	Start of product development
2004	6.4	1701.3	1866.5	Program restructured
2005	16.4	2929.9	4796.4	System of Systems Functional Review; system-of-systems requirements stabilized; cost estimate updated
2006	27.2	3168.8	7965.2	Initial preliminary design review; initial system level requirements
2007	38.9	3426.4	11391.6	Preliminary design work in progress
2008	50.8	3498.6	14890.2	Most technologies reach TRL 6; final system-level requirements
2009	61.6	3148.3	18038.5	Preliminary design review; most technologies reach TRL 6; mandated "go/no-go" review
2010	72.6	3226.9	21265.4	Limited user test 2; some prototypes available
2011	82	2778.6	24044	Critical design review; design readiness review; all system prototypes available
2012	88.4	1868.1	25912.1	Technologies reach full TRL 7 maturity; limited user test 3; initial system-of-systems demonstration
2013	92.9	1313.7	27225.8	Milestone C - initial production decision
2014	96.7	1115.2	28341	Limited user test 4; full system-of-systems demonstration; fielding start brigade combat teams
2015	99.6	857.2	29198.2	Initial operational capability
2016	100	107.3	29305.5	Initial operational test and evaluation; full-rate production decision
2017				Full operational capability

Source: U.S. Army (data); GAO (analysis and presentation).

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